LBERT R. MANN
LIBRARY
AT
RNELL UNIVERS

CORNELL UNIVERSITY LIBRARY
3 1924 053 959 338

DATE DUE

~~SEP 0 1 1989~~

~~JAN 1 8 1991~~

DEMCO 38-297

0
12
7
6

MYCOTAXON

AN INTERNATIONAL JOURNAL DESIGNED TO EXPEDITE PUBLICATION OF RESEARCH ON TAXONOMY & NOMENCLATURE OF FUNGI & LICHENS

Volume XXVII October-December 1986

CONTENTS

Studies on ectomycorrhizae III. Mycorrhizae formed by four fungi in the genera *Lactarius* and *Russula* on spruce . . . . R. AGERER 1

A new species of the genus *Oidium* from India. G. BAGYANARAYANA AND U. BRAUN 61

Coniochaetidium mirabile, a new ascomycete isolated from salted food. SHUN-ICHI UDAGAWA AND HARUO TSUBOUCHI 63

Materials for a lichen flora of the Andaman Inslands — I. M. B. NAGARKAR, P. K. SETHY, AND P. G. PATWARDHAN 71

Hyphomucor, a new genus in the Mucorales for *Mucor assamensis*. M. A. A. SCHIPPER 83

Metarhizium flavoviride var. *minus*, var. nov., a pathogen of plant- and leafhoppers on rice in the Philippines and Solomon Islands. MICHIEL C. ROMBACH, RICHARD A. HUMBER, AND DONALD W. ROBERTS 87

Studies on Chinese ascomycetes. 3. *Astrosphaeriella lageniformis*. JING-ZHU YUE AND OVE ERIKSSON 93

Thermophymatospora, a new thermotolerant genus of basidiomycetous hyphomycetes. SHUN-ICHI UDAGAWA, TAKEYOSHI AWAO, AND SAMIR K. ABDULLAH 99

Gibbago, a new phaeodictyoconidial genus of hyphomycetes. EMORY G. SIMMONS 107

A new species of the lichen genus *Sulcaria* (Ascomycotina, Alectoriaceae) from California . . . . IRWIN M. BRODO 113

Badarisama sojae, a new bulbil-forming genus and species. I. K. KUNWAR, J. B. MANANDHAR, AND J. B. SINCLAIR 119

Notes de nomenclature concernant les Hyménomycètes; IV. Sur quelques épithètes spécifiques préoccupés. 3 . . . . RÉGIS COURTECUISSE 127

Two new dematiaceous hyphomycetes from tropical forest litter. LAURA ZUCCONI AND SILVANO ONOFRI 147

Digitatispora lignicola, a new marine lignicolous Basidiomycotina. E. B. GARETH JONES 155

Marine fungi from Seychelles. VI. *Massarina velataspora*, a new marine Ascomycotina from mangrove wood . . . . K. D. HYDE AND B. D. BORSE 161

Taxonomic concepts in the Endogonaceae: III. The separation of *Scutellospora* gen. nov. from *Gigaspora* Gerd. & Trappe. CHRISTOPHER WALKER AND F. E. SANDERS 169

[CONTENTS continues overleaf]

ISSN 0093-4666 *MYXNAE 27 1-628 (1986)*

Published quarterly by MYCOTAXON, Ltd., P.O. Box 264, Ithaca NY 14851
For subscription details, availability in microfilm and microfiche, and availability of articles as tear sheets, see back cover.

[CONTENTS continued from front cover]

Five new species of *Parmelia* (Lichenes, Parmeliaceae) from southern Africa.
FRANKLIN A. BRUSSE 183
Hypogeous fungi from the southeastern United States I. The genus *Rhizopogon*.
STEVEN L. MILLER 193
Species of *Scutellospora* (Endogonaceae) with smooth-walled spores from maritime sand dunes: two new species and a redescription of the spores of *Scutellospora pellucida* and *Scutellospora calospora*.
R. E. KOSKE AND CHRISTOPHER WALKER 219
Four new effigurate-crustose species of *Parmelia* (Lichenes, Parmeliaceae) from southern Africa . . . . FRANKLIN A. BRUSSE 237
Bertiella (Sacc.) Sacc. & Sydow a synonym of *Massarina* Sacc.
OVE ERIKSSON AND JING-ZHU YUE 247
A new *Chlamydomyces* species from Italy . . . . CLAUDIA PERINI 255
Notes on Entomophthorales (Zygomycotina) collected by T. Petch: II. *Erynia ellisiana* sp. nov., non *Erynia forficulae* (Giard), comb. nov., pathogens of Forficulidae (Dermaptera) . . . . ISRAEL S. BEN-ZE'EV 263
Canoparmelia, Paraparmelia and *Relicinopsis*. Three new genera in the Parmeliaceae (lichenized Ascomycotina).
JOHN A. ELIX, JEN JOHNSTON, AND DOUGLAS VERDON 271
Two new discomycetes on *Pinus* . . . . A. FUNK 283
A comparison between *Phytophthora cryptogea* and *P. drechsleri*.
H. H. HO AND S. C. JONG 289
Tremellostereum (Tremellaceae) nov. gen. . . . . L. RYVARDEN 321
Basidiomycetes that decay Gambel oak in southwestern Colorado: III.
J. PAGE LINDSEY 325
Lahmia Körber (= *Parkerella* A. Funk) a misinterpreted genus with isolated position . . . . OVE ERIKSSON 347
Cultural studies in *Tubulicrinis* and *Xenasmatella* (Corticiaceae, Basidiomycetes).
NILS HALLENBERG 361
Foliicolous ascomycetes 7. Phylogenetic systematics of the Capnodiaceae.
DON R. REYNOLDS 377
NOTICE: Guide to Sanctioned Fungal Names 404
The use of isozyme analysis in fungal taxonomy and genetics.
J. A. MICALES, M. R. BONDE, AND G. L. PETERSON 405
The lichen flora of the Galápagos Islands, Ecuador . . . . WILLIAM A. WEBER 451
Platygloea acanthophysa, a new species with single sterigmate basidia and acanthophyses . . . . HAROLD H. BURDSALL, JR. 499
Macrochemical color reactions of macromycetes II. Chemical properties and systematic position of *Bondarzewia mesenterica* . . . . HARALD M. FRANK 503
East African rusts (Uredinales), mainly from Uganda 5. On families belonging to Gamopetalae . . . . HALVOR B. GJÆRUM 507
Confirmation of *Ascosphaera apis* in Georgia.
R. T. HANLIN AND R. A. SAUNDERS 551
Récoltes de *Biscogniauxia dennisii* (Pyrenomycetes, Ascomycetes) dans le sud-ouest de la France . . . . FRANÇOISE CANDOUSSAU 555
New species of the lichen genus *Xanthoparmelia* from southern Africa (Ascomycotina: Parmeliaceae) . . . . MASON E. HALE, JR. 563
New species of *Relicinia* (lichenized Ascomycotina) from Australasia.
JOHN A. ELIX AND JEN JOHNSTON 611

[CONTENTS continues inside back cover]

MYCOTAXON

AN INTERNATIONAL JOURNAL DESIGNED TO EXPEDITE PUBLICATION OF RESEARCH ON TAXONOMY & NOMENCLATURE OF FUNGI & LICHENS

ALBERT R. MANN
LIBRARY

DEC 17 1986

ITHACA, N.Y. 14853

VOLUME XXVII, 1986

COMPLETE IN ONE QUARTERLY ISSUE
CONSISTING OF iv + 628 PAGES
INCLUDING FIGURES

CO-EDITORS

G. L. HENNEBERT
French Language Editor & Book Review Editor

Laboratoire de Mycologie systématique et appliquée
Université de Louvain, B-1348 Louvain-la-Neuve, Belgium

RICHARD P. KORF
English Language Editor & Managing Editor

Plant Pathology Herbarium, Cornell University
Ithaca, New York 14853, USA

SUSAN C. GRUFF
Associate Editor & Index Editor

Plant Pathology Herbarium, Cornell University
Ithaca, New York 14853, USA

QK
600
M992
v.27
1986

Published by

MYCOTAXON, LTD., P.O. BOX 264, ITHACA NY 14851 USA

Printed in the United States of America

TABLE OF CONTENTS, VOLUME TWENTY-SEVEN

October-December 1986

Studies on ectomycorrhizae III. Mycorrhizae formed by four fungi in the genera *Lactarius* and *Russula* on spruce .... R. AGERER 1

A new species of the genus *Oidium* from India. G. BAGYANARAYANA AND U. BRAUN 61

Coniochaetidium mirabile, a new ascomycete isolated from salted food. SHUN-ICHI UDAGAWA AND HARUO TSUBOUCHI 63

Materials for a lichen flora of the Andaman Inslands — I. M. B. NAGARKAR, P. K. SETHY, AND P. G. PATWARDHAN 71

Hyphomucor, a new genus in the Mucorales for *Mucor assamensis*. M. A. A. SCHIPPER 83

Metarhizium flavoviride var. *minus*, var. nov., a pathogen of plant- and leafhoppers on rice in the Philippines and Solomon Islands. MICHIEL C. ROMBACH, RICHARD A. HUMBER, AND DONALD W. ROBERTS 87

Studies on Chinese ascomycetes. 3. *Astrosphaeriella lageniformis*. JING-ZHU YUE AND OVE ERIKSSON 93

Thermophymatospora, a new thermotolerant genus of basidiomycetous hyphomycetes. SHUN-ICHI UDAGAWA, TAKEYOSHI AWAO, AND SAMIR K. ABDULLAH 99

Gibbago, a new phaeodictyoconidial genus of hyphomycetes. EMORY G. SIMMONS 107

A new species of the lichen genus *Sulcaria* (Ascomycotina, Alectoriaceae) from California .... IRWIN M. BRODO 113

Badarisama sojae, a new bulbil-forming genus and species. I. K. KUNWAR, J. B. MANANDHAR, AND J. B. SINCLAIR 119

Notes de nomenclature concernant les Hyménomycètes; IV. Sur quelques épithètes spécifiques préoccupés. 3 .... RÉGIS COURTECUISSE 127

Two new dematiaceous hyphomycetes from tropical forest litter. LAURA ZUCCONI AND SILVANO ONOFRI 147

Digitatispora lignicola, a new marine lignicolous Basidiomycotina. E. B. GARETH JONES 155

Marine fungi from Seychelles. VI. *Massarina velataspora*, a new marine Ascomycotina from mangrove wood .... K. D. HYDE AND B. D. BORSE 161

Taxonomic concepts in the Endogonaceae: III. The separation of *Scutellospora* gen. nov. from *Gigaspora* Gerd. & Trappe. CHRISTOPHER WALKER AND F. E. SANDERS 169

Five new species of *Parmelia* (Lichenes, Parmeliaceae) from southern Africa. FRANKLIN A. BRUSSE 183

Hypogeous fungi from the southeastern United States I. The genus *Rhizopogon*. STEVEN L. MILLER 193

Species of *Scutellospora* (Endogonaceae) with smooth-walled spores from maritime sand dunes: two new species and a redescription of the spores of *Scutellospora pellucida* and *Scutellospora calospora*. R. E. KOSKE AND CHRISTOPHER WALKER 219

Four new effigurate-crustose species of *Parmelia* (Lichenes, Parmeliaceae) from southern Africa .... FRANKLIN A. BRUSSE 237

Bertiella (Sacc.) Sacc. & Sydow a synonym of *Massarina* Sacc. OVE ERIKSSON AND JING-ZHU YUE 247

A new *Chlamydomyces* species from Italy .... CLAUDIA PERINI 255

Notes on Entomophthorales (Zygomycotina) collected by T. Petch: II. *Erynia ellisiana* sp. nov., non *Erynia forficulae* (Giard), comb. nov., pathogens of Forficulidae (Dermaptera) .... ISRAEL S. BEN-ZE'EV 263

Canoparmelia, Paraparmelia and *Relicinopsis*. Three new genera in the Parmeliaceae (lichenized Ascomycotina).
JOHN A. ELIX, JEN JOHNSTON, AND DOUGLAS VERDON 271
Two new discomycetes on *Pinus* . . . . A. FUNK 283
A comparison between *Phytophthora cryptogea* and *P. drechsleri*.
H. H. HO AND S. C. JONG 289
Tremellostereum (Tremellaceae) nov. gen. . . . . L. RYVARDEN 321
Basidiomycetes that decay Gambel oak in southwestern Colorado: III.
J. PAGE LINDSEY 325
Lahmia Körber (= *Parkerella* A. Funk) a misinterpreted genus with isolated position . . . . OVE ERIKSSON 347
Cultural studies in *Tubulicrinis* and *Xenasmatella* (Corticiaceae, Basidiomycetes).
NILS HALLENBERG 361
Foliicolous ascomycetes 7. Phylogenetic systematics of the Capnodiaceae.
DON R. REYNOLDS 377
NOTICE: Guide to Sanctioned Fungal Names 404
The use of isozyme analysis in fungal taxonomy and genetics.
J. A. MICALES, M. R. BONDE, AND G. L. PETERSON 405
The lichen flora of the Galápagos Islands, Ecuador . . . . WILLIAM A. WEBER 451
Platygloea acanthophysa, a new species with single sterigmate basidia and acanthophyses . . . . HAROLD H. BURDSALL, JR. 499
Macrochemical color reactions of macromycetes II. Chemical properties and systematic position of *Bondarzewia mesenterica* . . . . HARALD M. FRANK 503
East African rusts (Uredinales), mainly from Uganda 5. On families belonging to Gamopetalae . . . . HALVOR B. GJÆRUM 507
Confirmation of *Ascosphaera apis* in Georgia.
R. T. HANLIN AND R. A. SAUNDERS 551
Récoltes de *Biscogniauxia dennisii* (Pyrenomycetes, Ascomycetes) dans le sud-ouest de la France . . . . FRANÇOISE CANDOUSSAU 555
New species of the lichen genus *Xanthoparmelia* from southern Africa (Ascomycotina: Parmeliaceae) . . . . MASON E. HALE, JR. 563
New species of *Relicinia* (lichenized Ascomycotina) from Australasia.
JOHN A. ELIX AND JEN JOHNSTON 611

Author INDEX 617
INDEX to Fungous and Lichen Taxa 619
Reviewers 627
Publication date, MYCOTAXON Volume 26 627
Errata 628

MYCOTAXON

Vol. XXVII, pp. 1-59 October-December 1986

Studies on Ectomycorrhizae III *

Mycorrhizae Formed by four Fungi in the Genera Lactarius and Russula on Spruce

R. AGERER

Institute for Systematic Botany, University of Munich
D-8000 Munich
Menzingerstraße 67

This series describes mainly anatomical and morphological studies on ectomycorrhizae. Keys to the characterized mycorrhizae will be provided. In later papers of this series, the keys will be enlarged by inclusion of newly described mycorrhizae. In part II of the series the methods of characterization and identification applied in this series are described comprehensively.

SUMMARY

The anatomical and morphological characteristics of four identified ectomycorrhizae are described. The mycorrhizae of Lactarius deterrimus, L. picinus, Russula ochroleuca and R. xerampelina were identified by tracing hyphal connections between the fruitbodies and the mycorrhizae. The four mycorrhizae are characterized by striking differences. Besides variations in the structure of the mantle, there are differences of colour and shape of the mycorrhizae, and of their attached rhizomorphs, different colour reactions with reagents, and differences regarding laticiferous hyphae and Hartig net. All mycorrhizae belong to the so-called smooth type. Their features are compared with those described in the literature as being typical of these or related species.

---

* AGERER, R. (1986) - Studies on Ectomycorrhizae II. - Introducing remarks on characterization and identification. Mycotaxon 26: 473 - 492.

KEY WORDS
ectomycorrhizae-characterization, -identification, -anatomy, -morphology, -surface view, -longitudinal section, -cross section, inner surface of mantle, chemical reaction, autofluorescence, nucleus, siderophilous granulation, emanating hyphae, rhizomorph, cystidia, laticiferous hyphae, *Picea abies, Lactarius deterrimus, L. picinus, Russula ochroleuca, R. xerampelina,* key.

I KEY FOR THE CHARACTERIZED MYCORRHIZAE

1 Mantle of mycorrhizae with laticiferous hyphae
  2 Surface of mantle with normal hyphae running more or less parallel to the surface of the mycorrhizae
    Lactarius deterrimus
  2 Surface of mantle with short, obtuse hyphal ends protruding more or less perpendicularly to the surface of mantle
    Lactarius picinus
1 Mantle of mycorrhizae without laticiferous hyphae
  3 Surface of mantle pseudoparenchymatous, cells angular
    Russula ochroleuca
  3 Surface of mantle a network of hyphae
    Russula xerampelina

II DESCRIPTIONS OF THE MYCORRHIZAE

1. LACTARIUS DETERRIMUS Gröger

Fig. 1, 2, 3, Pl. 1, 2.

MORPHOLOGICAL CHARACTERS

Ramification: monopodial; *length of unramified ends:* up to 2,1 mm; *diametre of unramified ends:* 0,32 - 0,52 (0,65) mm; *shape of unramified ends:* straight or slightly twisted, sometimes more or less flat; *structure of surface:* even, with some rhizomorphs.
Colour of unramified ends: bright copper-orange; *colour of tips:* bright copper-orange; *colour of older parts:* brown with dark green patches.

ANATOMICAL CHARACTERS OF SURFACE

OUTER SURFACE OF MANTLE
Structure: plectenchymatous, individual hyphae recognizable; size of hyphal cells: (2) 3 - 4 µm; thickness of cell walls: not conspicuously thick-walled; surface of the very tip: plectenchymatous, hyphae strongly agglutinated, 2 - 3 (3,5) µm thick; laticiferous hyphae, 3 - 7 µm in diam., with 0,5 - 1 µm thick walls, contents yellow.
RHIZOMORPHS
Shape in cross-section: more or less round; arrangement and diameter of hyphae: hyphae more or less parallel, without thicker central hyphae, 2,5 - 3,5 µm in diam., rarely with laticiferous hyphae, scarcely thicker than the other hyphae; thickness of cell walls: not conspicuously thick-walled; colour of hyphae: pigment membranaceous, slightly yellowish; septae: without clamp connections; anastomoses: rare, hyphae agglutinated.
EMANATING HYPHAE
Shape and diameter: more or less straight, ca. 2,5 µm in diam, seldom to be found; thickness of cell walls: ca. 0,5 µm; colour of hyphae: more or less colourless; septae: without clamps.
CYSTIDIA none found.
INNER SURFACE OF MANTLE
Arrangement of hyphae: irregular, hyphae short or longer; diameter of hyphae: (2) 3 - 4 (7) µm.

ANATOMICAL CHARACTERS, CROSS-SECTION

MANTLE
Thickness and differentiation: (10) 20 - 30 (40) µm, strongly agglutinated, hyphal walls strongly swollen; cell-shape and dimensions of different layers: no differentiated layers recognizable, hyphae tangentially 2 - 10 (15) µm, radially 1 - 2,5 µm, laticiferous hyphae tangentially 4 - 20(40) µm, radially 4 - 5 µm.
TANNIN CELLS
Number of rows: 1 - 2; shape and measure: narrow, tangentially oriented, 30 - 40 x 5 - 10 µm.

HARTIG NET

Shape and dimensions of cortex cells: tangentially-oval, 30 - 60 x (10) 15 - 20 (30) µm; depth of H'net: 3 rows including tannin cells, one row next the endodermis being free of H'net; thickness of H'net: (5) 6 - 7 (8) µm; number of hyphal rows of H'net: 1 ; shape of H'net cells in section: oval, but often distinctly stretched.

ANATOMICAL CHARACTERS, LONGITUDINAL SECTION

MANTLE

Shape and dimensions of the cells of the very tip: like the hyphae of the remaining part of the mycorrhiza, but hyphae less agglutinated; shape and dimensions of cells in different layers: no distinct layers recognizable, hyphae tangentially 2 - 10 (20) µm, radially 2 - 3 (5) µm.

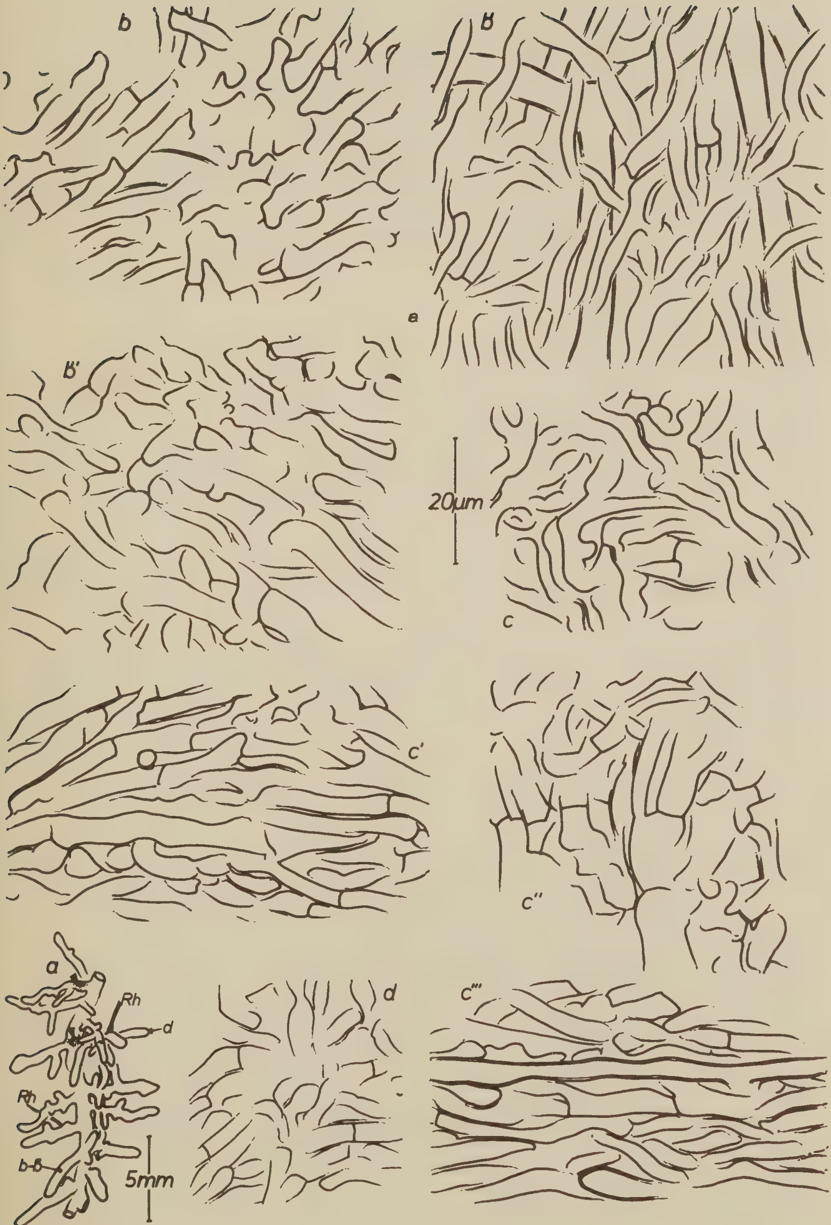
HARTIG NET

Shape and dimensions of cortex cells: flat rhombic to oval, more or less parallel to the axis of the mycorrhiza, 60 - 110 x 12 - 20 (30) µm; shape and dimensions of tannin cells: flat, parallel to the axis of the mycorrhiza, 50 - 90 (120) x 5 - 12 µm, inner tannin cell layer up to 15 µm thick.

COLOUR REACTION IN DIFFERENT REAGENTS

Acetic-Fuchsin: ----; a-Naphtol: ----; Ammonium-Hydroxide: ochre-orange, especially laticiferous hyphae; Brilliant-Kresyl-Blue: bluish-green, laticiferous hyphae conspicuous, after treatment with water violet blue, laticiferous hyphae distinctly green; Chlorazol-Black E: slightly bluish- green; Cotton-Blue: slightly blue; Erythrosin: reddish, especially thin laticiferous hyphae; Fast-Green: green, especially laticiferous hyphae; Gujak:

Fig. 1 - *Lactarius deterrimus* - a: Habit of mycorrhizae. - b, b', b'': different surface views. - c, c',c'', c''': inner surface of mantle, different views. - d: Surface view of the very tip. (All figs. from O/2028, in Herb. R. Agerer).


b
B
a
b'
20µm
c
c'
c''
a
Rh
d
Rh
b-b
5mm
d
c'''

----; Iron-Sulfate: ----; KOH 15%: ochre-orange, especially laticiferous hyphae; Kongo-Red: slightly blood-red; Magnesium-Acetate: ----; Malachit-Green: green, especially laticiferous hyphae; Martius-Yellow: ----; Melzer's Reagent: ----; Phenol: ----; Phenol-Anilin: ----; Phloxin B: reddish, especially laticiferous hyphae; Stahl's EP-Reagent: ?; Sulfo-Vanillin: laticiiferous hyphae with dark granules; Toluidin-Blue: violet blue.

AUTOFLUORESCENCE

WHOLE MYKORRHIZA
UV 254 nm: ----; UV 366 nm: ----.
MANTLE AND RHIZOMORPHS
UV-filter 340 - 380 nm: blue, laticiferous hyphae distinctly blue; BLUE-filter 450 - 490 nm: greenish, laticiferous hyphae distinctly green.

STAINING OF NUCLEI

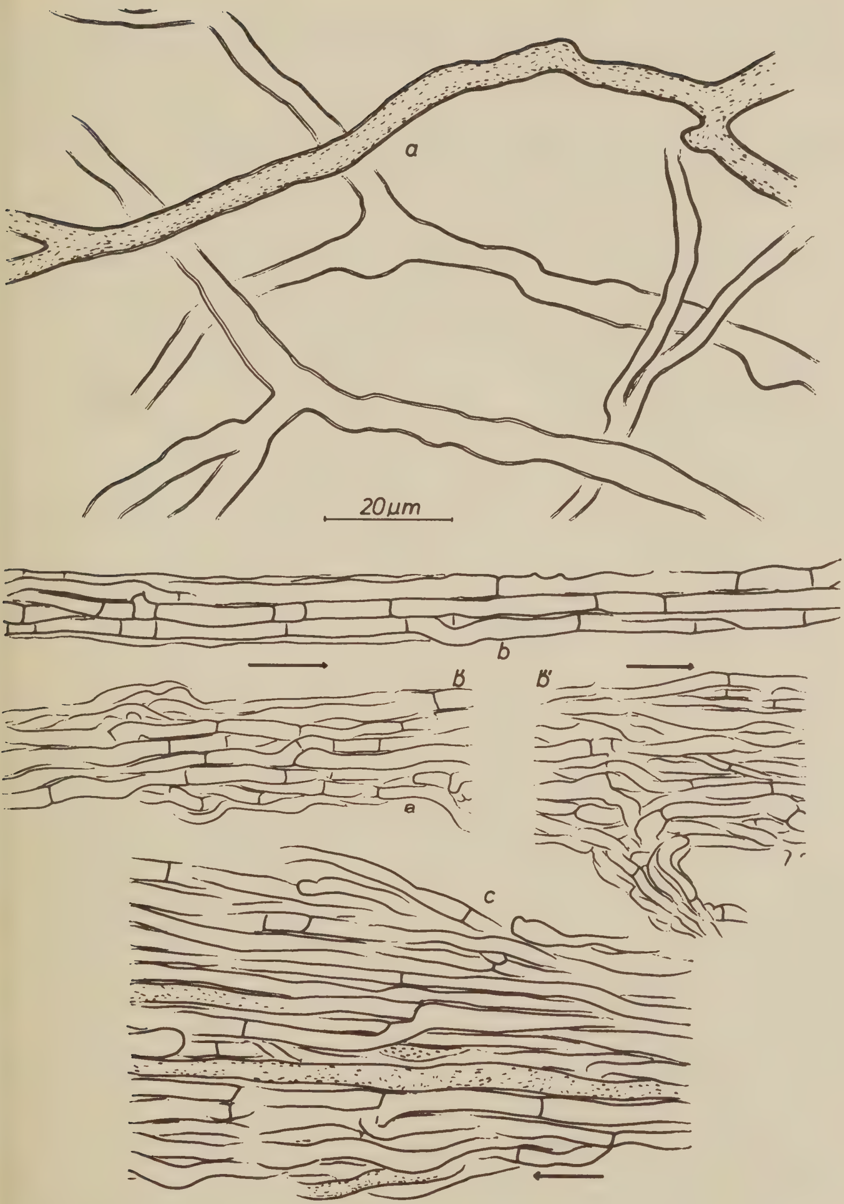
Hyphal cells of outer mantle surface with two nuclei lying mostly close together, seldom hyphal cells with 3 or 4 nuclei (method: aceto-carmine). Siderophilous reaction negative.

MATERIAL STUDIED AND METHOD OF IDENTIFICATION

Germany, Bavaria, München-Oberschleißheim, Korbiniani-Hölzl, Versuchsfläche O, Quadrat 2028, 12. 7. 1983; Herb. RA 2028(12.7.83); with Picea abies (material for microscopical studies). - Germany, Bavaria, München-Oberschleißheim, Korbiniani-Hölzl, bei Versuchsfläche O, Herb. RA Oa(22.9.84), with Picea abies (material for staining). There were direct connections between

---

Fig. 2 - Lactarius deterrimus - a: Surface view of laticiferous hyphae. - b, b', b'': Rhizomorphs (arrows indicate the distal direction). - c: Rhizomorph of basis of fruitbody. (Figs. a - b'' from O/2028 in Herb. R. Agerer, fig. c from Oa (22. 9. 84) in Herb. R. Agerer).


a
20 µm
b
b'
b''
a
c

mycorrhizae and the rhizomorphs of the base of fruitbody.

COMPARISON OF THE MYCORRHIZA OF LACTARIUS DETERRIMUS WITH THOSE OF L. PICINUS

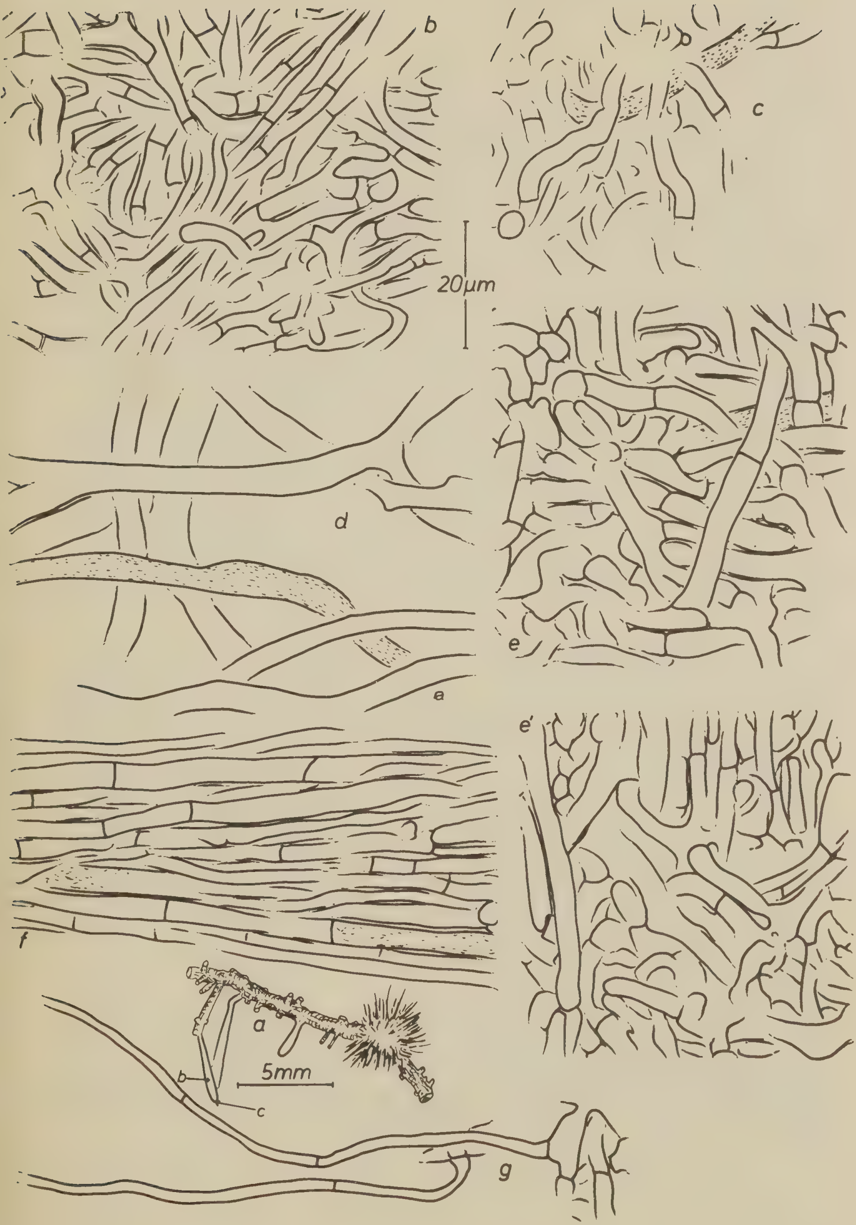
(Selected features only)

The mycorrhizae of Lactarius deterrimus differ considerably from those of L. picinus.
(1) Morphological characters: Whereas L. picinus forms pyramidal, densely ramified mycorrhizae, those of L. deterrimus are mostly more or less pinnate and the individual mycorrhizae are relatively scattered. Additionally the terminal portions of the mycorrhizae are much longer in L. deterrimus than in L. picinus. Besides the different colour (brightly copper-orange with olive-green patches in L. deterrimus, fleshy-brown in L. picinus) the gross morphology of the surfaces deviates fundamentally. The surface of the mycorrhiza of L. picinus is pruinose, that of L. deterrimus is smooth.

The most obvious structural differences between the two mycorrhizae are found in the mantle. In L. deterrimus the mantle surface is composed of more or less undifferentiated hyphae whereas those of L. picinus form special endcells which project more or less perpendicularly to the surface. A second difference regards the diameter of the laticiferous hyphae: in L. picinus they are distinctly broader than in L.deterrimus. Moreover, sectioned mycorrhizae of L. picinus show a three-layered mantle; that of L. deterrimus is more or less homogenous. The rhizomorphs of L. picinus possess broader hyphae in the centre than in the periphery, those of L. deterrimus are of

---

Fig. 3 - Lactarius deterrimus - a: Habit of mycorrhiza and fruitbody primordium. - b: Surface view. - c: Surface view of the very tip. - d: Surface view of laticiferous hyphae. - e, e': Inner surface of mantle, different views. - f: Rhizomorph of the basis of fruitbody. - g: Emanating hyphae. (All figs. from Oa(22. 9. 84) in Herb. R. Agerer).


b
b
c
20µm
d
e
e
e'
f
a
5mm
b
c
g

of more or less uniform hyphae, with septae at short intervals.

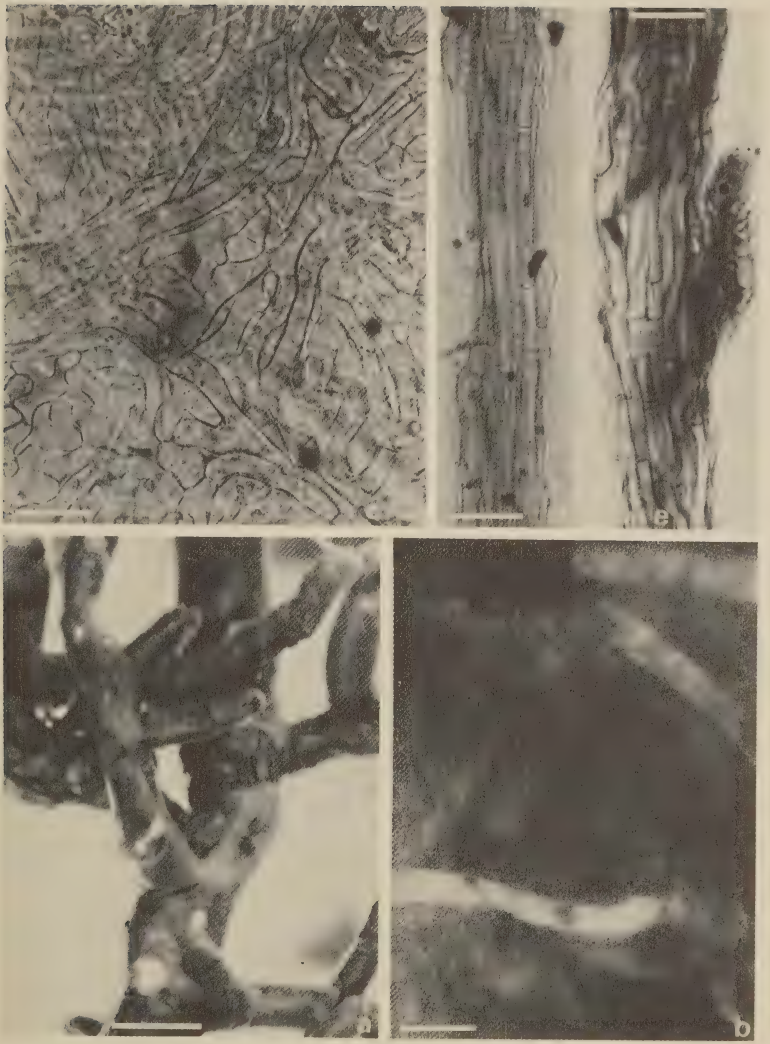
Within the cortex, cells of the Hartig net in L. picinus are thinner than in L. deterrimus.

(2) Characters after treatment with different reagents: In alkalies (KOH and Ammonium-hydroxide) the mantle hyphae of Lactarius deterrimus become orange-ochre, especially the lactiferous hyphae whereas L. picinus do not show such reactions. Another difference is due to Iron-sulfate: only the mycorrhiza of L. picinus turns greenish-brown. Third, only in L. picinus does Melzer's reagent tinge the mantle yellowish-brown, especially the laticiferous hyphae. There are some other slight differences in color-reactions, but they are not disctinctive enough to differentiate these two species. We found no mention of colour reactions of L. deterrimus with the above mentioned reagents in literature (SCHMITT 1973, MOSER 1978). Only ROMAGNESI (1958) mentions for L. deterrimus (= Lactarius deliciosus var. picinus) a reaction with Gujak. Unfortunately we did not check this reagent with fresh mycorrhizae of L. deterrimus.

MYCORRHIZAE OF LACTARIUS DETERRIMUS AS TREATED IN LITERATURE

This species was described rather recently (GRÖGER 1968), and no information about its mycorrhizae is available. Of the section Dapetes only L. deliciosus and L. sanguifluus is dealt with in the literature. But the researches on this species probably refer to more than L. deliciosus s. str.

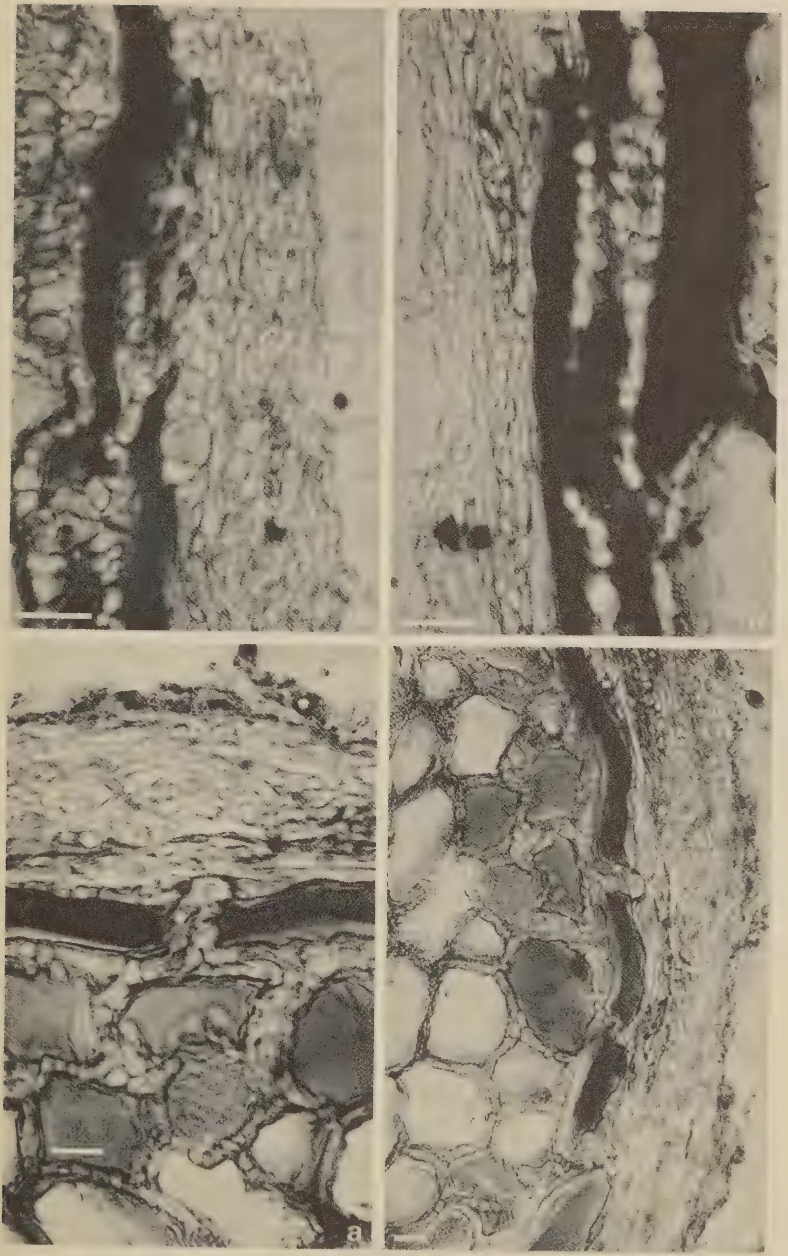
Pl. 1 - Lactarius deterrimus -a: Habit of mycorrhizae. - b: Autofluorescence of laticiferous hyphae (Blue-filter). - c: Inner surface of mantle. - d, e: Rhizomorphs. (Figs. a, d, e from 0/2028 in Herb. R. Agerer, figs. b, c from Oa(22. 9. 84) in Herb. R. Agerer). - Bar 1 mm (fig. a), 10 µm (fig b - e).


e
a
b

Similar, closely related species in this group were possibly included, because the species concepts had not been well defined untill recently.

HATCH & HATCH (1933) isolated cultures of *Lactarius deliciosus* from fruitbodies and synthesized mycorrhizae with *Pinus* species. They noted that the most abundant associated trees were *Pinus* and *Betula* species; *Lactarius deliciosus* is known as a species associated with pines but not of *Picea* , in contrast to *L. deterrimus.* The authors confirmed the ability of *L. deliciosus* to form mycorrhizae but provided no detailed description showing only a longitudinal section through the mycorrhiza. A plectenchymatous mantle and a Hartig net including up to three rows of cortex cells were characterizing features.
RIFFLE (1973) isolated cultures from sporocarps of *Lactarius deliciosus* growing with *Pinus ponderosa* and synthesized mycorrhizae with seedlings of this tree. Without doubt, this fungus was correctly identified, because *Pinus* was the host. The pictures of the sectioned mycorrhizae resemble the above described mycorrhiza of *L. deterrimus.* The mantle is plectenchymatous. RIFFLE (1973) mentions, however, that in his cultures no rhizomorphs grew. This may be due to the high nutrient status of the agar medium used for synthesizing mycorrhizae. The colour of the synthesized mycorrhiza of *L. deliciosus* was cream to tan and not brightly copper-orange. The dichotomously forked mycorrhizae of *L. deliciosus* + *Pinus ponderosa* are typical of pine species (BRUCHMANN 1874, MELIN 1923, MODESS 1941, SLANKIS 1948).

Pl. 2 - *Lactarius deterrimus* - a, b: Cross sections. - c,d: Longitudinal sections. (All figs. from O/2028 in Herb. R. Agerer). - Bar for all figs. 10 µm.


a

ASCAI & LARGENT (1983) found fruitbodies of Lactarius deliciosus s.l. associated with Abies concolor but it is questionable if this is the species in the restricted sense. In Europe Lactarius salmonicolor is only asssociated with Abies(alba). But this species has almost no bloom of green and therefore it would be very surprising if this species produces metallic green and gray mycorrhizae as ACSAI & LARGENT mentioned. The plectenchymatic mantle (prosenchymatic in the authors' terms) apparently resembles the mantle of L. deterrimus. Unfortunately further descriptions of the mycorrhizae by ACSAI & LARGENT are not provided.

MELIN (1924) used an orange milking Lactarius from gymnosperm forests (determined as L. deliciosus) for his successful syntheses of mycorrhizae with Pinus montana. He showed a cross section of the mycorrhiza. A dense plectenchymatous mantle - as we found for L. deterrimus - and a Hartig net with several rows of hyphal cells are the most important features shown by MELIN. He remarks that the emanating hyphae break off very easily, as we found for the mycorrhiza of L. deterrimus on Picea abies.

HATCH & DOAK (1933) showed, for the purpose of explaining some features of root systems the habit and a longitudinal section of the synthesized mycorrhiza of Lactarius deliciosus + Pinus strobus but they gave no detailed description. Their photographs of rhizomorphs of the synthesized mycorrhizae are noteworthy.

It is very surprising that none of the above mentioned authors have found laticiferous hyphae.

ZAK (1971a) described only the morphology, colour and natural changes of colour of synthesized mycorrhizae of Lactarius sanguifluus + Pseudotsuga menziesii.

2. LACTARIUS PICINUS Fr.

Fig. 4, 5, 6, Pl. 3, 4.

MORPHOLOGICAL CHARACTERS

Ramification: monopodially pyramidal; length of unramified ends: - 0,4 (0,5) mm; diameter of unramified ends: (0,35) 0,42 - 0,45 (0,6) mm; shape of unramified ends: straight, seldom slightly bent; structure of surface: more or less smooth, with some rhizomorphs.
Colour of unramified ends: fleshy-brown with white, farinose cover; colour of tips: like the other parts; colour of older parts: light umbre-brown.

ANATOMICAL CHARACTERS OF SURFACE

OUTER SURFACE OF MANTLE
Structure: plectenchymatous with short cylindrical or ovoid projecting hyphal ends, intermixed with slightly yellowish cells with tiny granular contents, laticiferous hyphae present, 7 - 9 µm in diam., slightly yellowish, walls up to 1 µm thick; size of hyphal cells: 3 - 4 µm in diam.; thickness of cell walls: inconspicuous; surface of the very tip: slightly pseudoparenchymatous, without or only occasionally with short cylindrical or ovoid projecting hyphal ends.
RHIZOMORPHS
Shape in cross-section: more or less round; arrangement and diameter of hyphae: central hyphae more or less parallel to the axis, the innermost 10 - 15 (20) µm thick, remaining central hyphae and irregularly woven ones, and projecting hyphae 3 - 4 µm thick; thickness of cell walls: central, thick hyphae up to 2,5 µm, remaining hyphae 1 (1,5) µm; colour of hyphae: more or less colourless; septae: clampless; anastomoses: rare, hyphae mostly connected by strong agglutination.

EMANATING HYPHAE
Shape and diameter: occasionally ramified, with

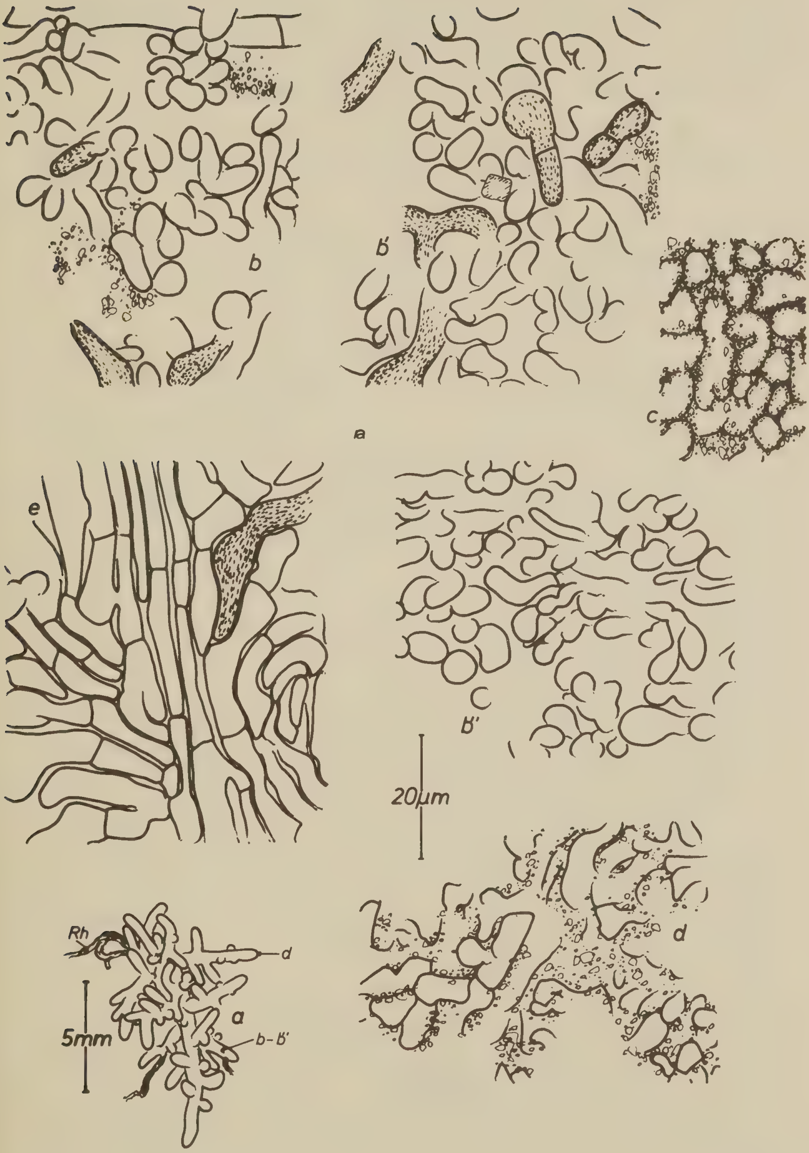
blunt ends, ca. 2 µm in diam.; thickness of cell walls: slightly thick-walled, thinner than 0,5 µm; colour of hyphae: more or less colourless; septae: clampless, rare.
CYSTIDIA none, exclusive of the special, projecting hyphae of the surface.
INNER SURFACE OF MANTLE
Arrangement of hyphae: mostly irregular, but sometimes with strandlike arrangements, short but more often relatively long; diameter of hyphae: 2,5 - 3,5 (5) µm.

ANATOMICAL CHARACTERS, CROSS-SECTION

MANTLE
Thickness and differentiation: 40 - 60 µm, distally thicker than on the remaining parts of the mycorrhizae, differentiated into three layers; cell-shape and hyphal dimensions of different layers: outermost layer with radially arranged hyphal ends, radially 3 - 10 (15) µm, tangentially 3 - 6 (10) µm, innermost layer tangentially 5 - 10 um, radially 3 - 5 µm, remaining layer with hyphae 2 - 3,5 µm in diam, slightly tangentially longish, laticiferous hyphae 4,5 - 8 (10) µm thick.
TANNIN CELLS
Number of rows: 1 - 2; shape and dimensions: narrow or broader elliptic, outer row slightly narrower than inner, 30 - 50 (80) x (5) 7 - 10 (20) µm.
HARTIG NET
Shape and dimension of cortex cells: round or slightly elliptical, mostly radially oriented, nearest to the endodermis often tangentially oriented, (12) 15 - 25 (30) µm; depth of H'net: 4 - 5 rows inclusive of tannin cells; thickness of H'net: between tannin cells 2 - 5 µm, conspicuous, between cortex cells 2 - 3 µm, inconspicuous; number of hyphal rows of H'net: mostly 1, between tannin cells often 2, outer tannin cells mostly

---

Fig. 4 - Lactarius picinus - a: Habit of mycorrhizae. - b, b', b'': Different surface views. - c: Surface view of mycorrhiza, densely covered with soil particles. - d: Surface view of the very tip. - e: Inner surface of mantle. (All figs. from RA 10745 in Herb. R. Agerer).


b
b'
c
a
e
b'
20µm
Rh
d
5mm
a
b-b'
d

separated by triangular projections of the inner mantle layer; *shape of H'net cells in section:* between and near tannin cells more or less round, between cortex cells probably mostly radially elongated, cell walls inconspicuous.

ANATOMICAL CHARACTERS, LONGITUDINAL SECTION

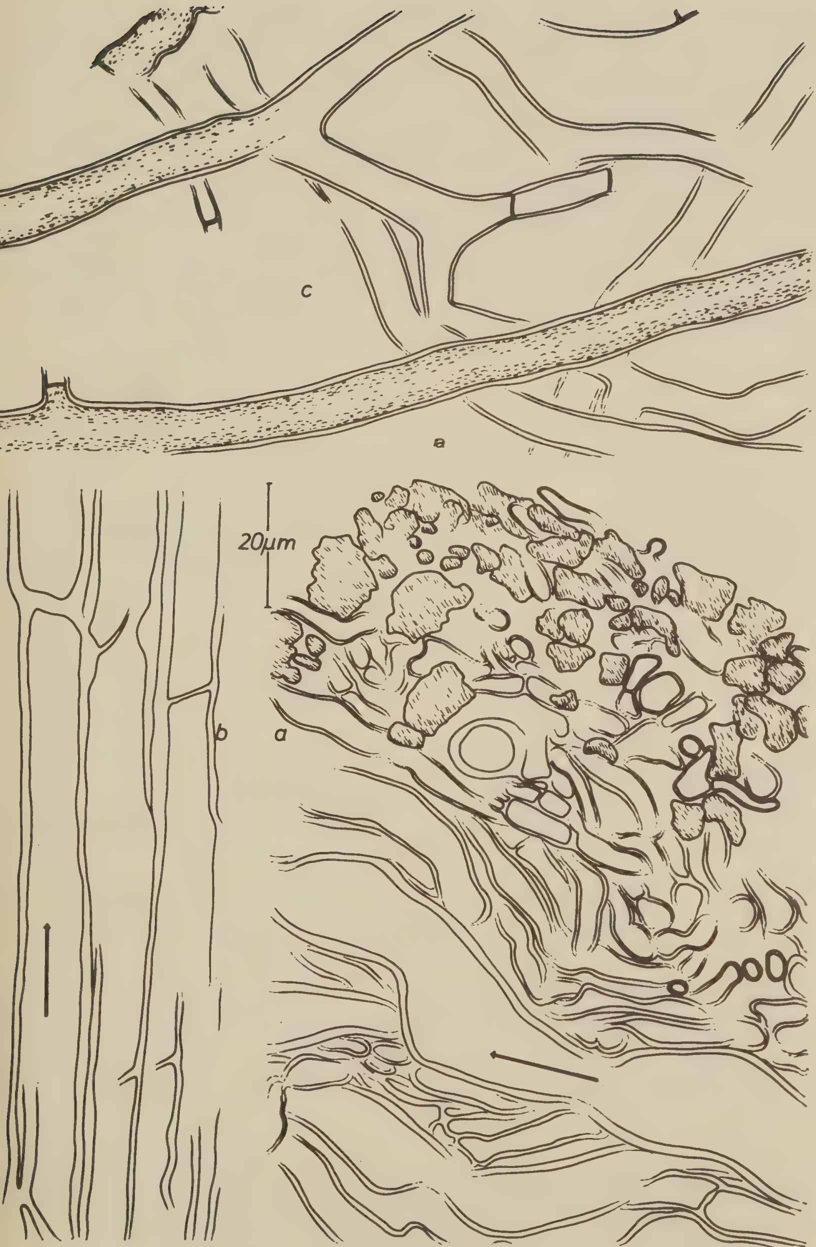
MANTLE

Shape and dimensions of the hyphae of the very tip: mantle 40 - 60 µm thick, only two layers present, innermost layer not specialized, middle layer distinctly thicker, hyphae more or less parallel to the surface of root, hyphae of this layer somewhat thicker than those of the remaining part of the mycorrhiza, 1,5 - 3 µm; *differentiation through older parts of the mantle:* mantle only 35 - 45 um thick, with three layers; *shape and dimensions of cells in different layers:* outermost layer with hyphae tangentially 3 - 6 (10) µm, radially 3 - 10 (15) µm, innermost layer with hyphae tangentially (3) 5 - 10 (15) µm, radially (2) 3 - 6 µm, remaining layer with hyphae tangentially (3) 5 - 15 (20) µm, radially 1 - 2,5 (3) µm, laticiferous hyphae tangentially 5 - 30 (45) µm, radially 5 - 9 µm.

HARTIG NET

Shape and dimensions of tannin cells: irregularly cylindrical or irregularly longish, parallel to the axis or oriented in a slightly oblique way to inside backwards, (30) 60 - 100 (120) x 10 - 20 (30) µm; *shape and dimensions of cortex cells:* irregularly rectangular or irregularly rhombic, oriented in a slight or conspicuous oblique way to inside backwards, 40 - 80 (100) x (15) 20 - 25 (30) µm.

Fig. 5 - *Lactarius picinus* - a: Longitudinal section through rhizomorph. - b: Longitudinal section through rhizomorph, detail from the centre. - c: Surface view of laticiferous hyphae. Arrows indicate the distal direction. (All figs. from RA 10745 in Herb. R. Agerer).


c
a
20µm
b
a

COLOUR REACTION IN DIFFERENT REAGENTS

Acetic-Fuchsin: slightly pink, laticiferous hyphae partly intensively pink; a-Naphtol: ----; Ammonium-Hydroxide: ----; Brilliant-Kresyl-Blue: blueish-green, laticiferous hyphae green, after treatment with water violet blue, laticiferous hyphae distinctly bluish-green; Chlorazol-Black E: greyish-blue, laticiferous hyphae more intensive; Cotton-Blue: bluish; Erythrosin: pinkish-brown, laticiferous hyphae plasmatically red; Fast-Green: green, laticiferous hyphae dark green; Gujak: ----; Iron-Sulfate: greenish-brown; KOH 15%: ----;

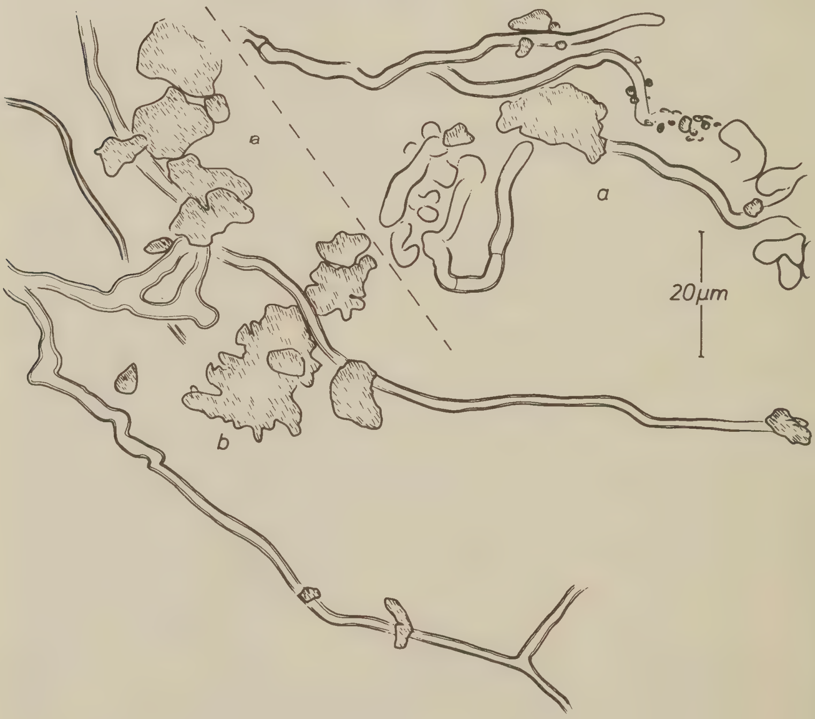


Fig. 6 - Lactarius picinus - a: Emanating hyphae from mycorrhiza. - b: Emanating hyphae from rhizomorph. (All figs. from RA 10745 in Herb. R. Agerer).

Kongo-Red: brownish-red; Magnesium-Acetate: ----; Malachit-Green: green, laticiferous hyphae more intensive; Martius-Yellow: slightly yellowish, laticiferous hyphae a little more intensive; Melzer's Reagent: yellowish-brown, laticiferous hyphae distinctly brownish; Phenol: ----; Phenol-Anilin: ----; Phloxin B: pinkish-brown, laticiferous hyphae more intensive; Stahl's EP-Reagent: ----; Sulfo-Vanillin: light red, laticiferous hyphae dark carmine; Toluidin-Blue: violet blue.

AUTOFLUORESCENCE

WHOLE MYKORRHIZA
UV 254 nm: ----; UV 366 nm: ----.
MANTLE AND RHIZOMORPHS
UV-filter 340 - 380 nm: laticiferous hyphae distinctly blue-green, remaining hyphae slightly blue-green; BLUE-filter 450 - 490 nm: laticiferous hyphae distinctly green remaining hyphae slightly green.

STAINING OF NUCLEI

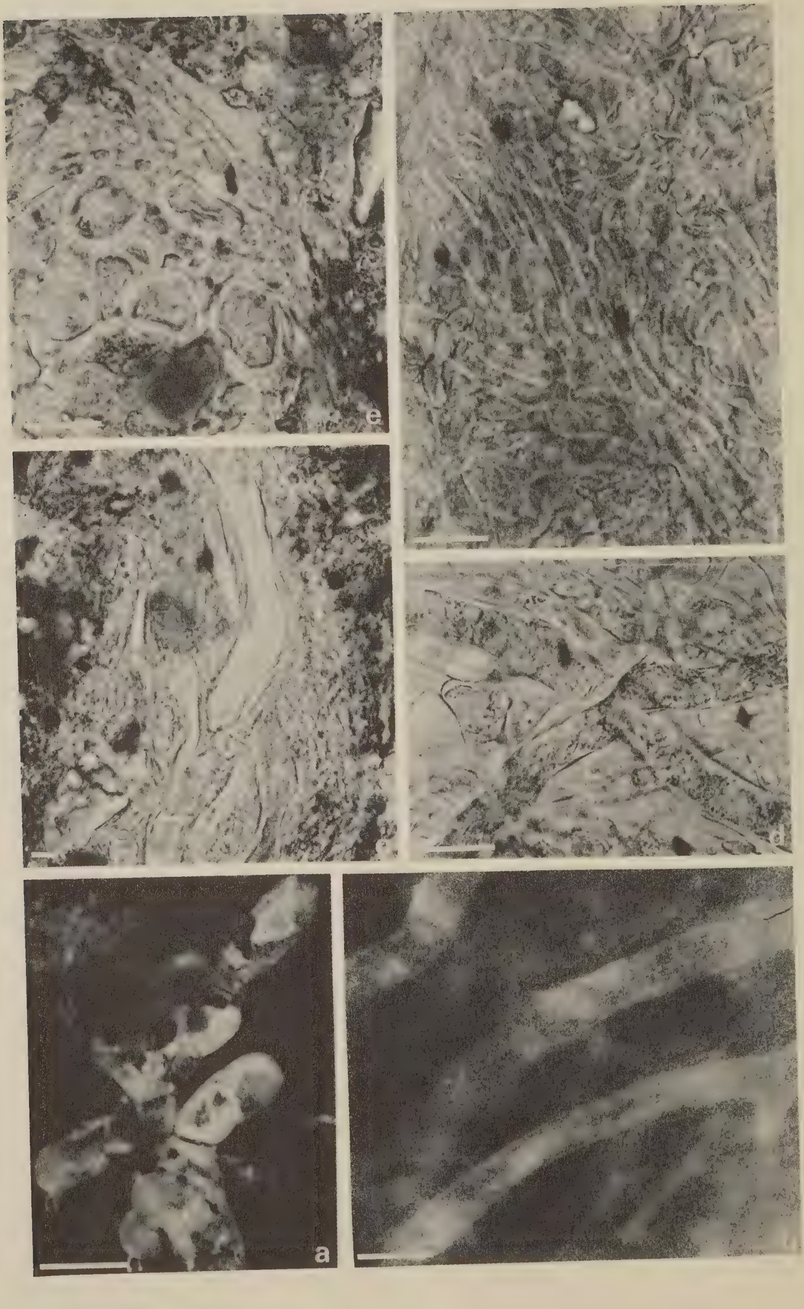
Cells of projecting hyphae and longer hyphae below these cells mostly with 2 nuclei, lying close together, longer hyphae seldom with more than two nulei (4 - 6). (Method: aceto-carmine). Siderophilous reaction negative.

MATERIAL STUDIED AND METHOD OF IDENTIFICATION

Germany, Bavaria, Buchenau bei Fürstenfeldbruck, 2. 10. 1984; with Picea abies; reference specimen of mycorrhiza and fruitbody RA 10745 in Herb. R. Agerer. There were some connections between base of fruitbody and mycorrhizae by rhizomorphs.

COMPARISON OF THE MYCORRHIZA OF LACTARIUS PICINUS WITH THOSE OF L. DETERRIMUS

(See comments on L. deterrimus)


e
c
d
a

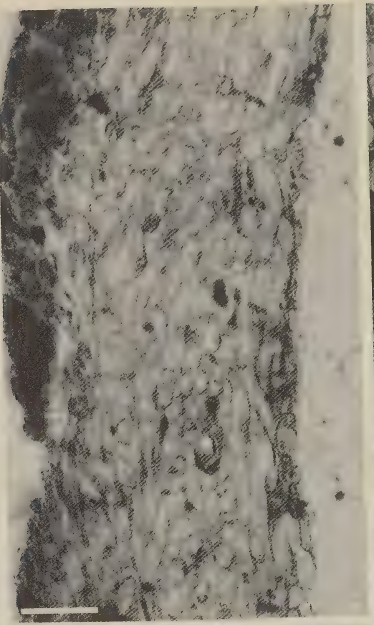
MYCORRHIZAE OF LACTARIUS PICINUS AS TREATED IN LITERATURE

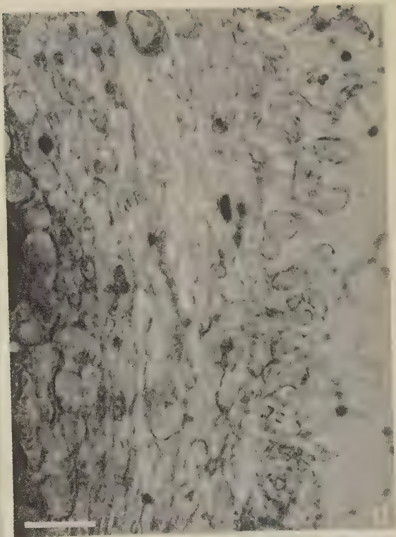
No mycorrhiza formed by this species has been discribed. This is true for all species of the section Plinthogali of this genus.

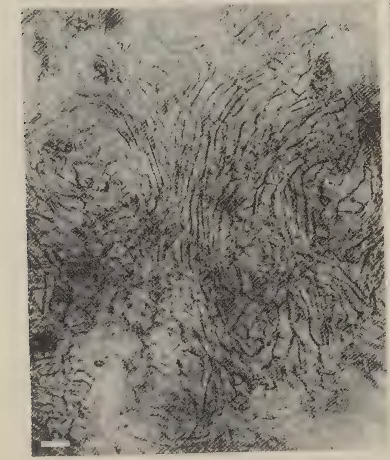
Plate 4: overleaf

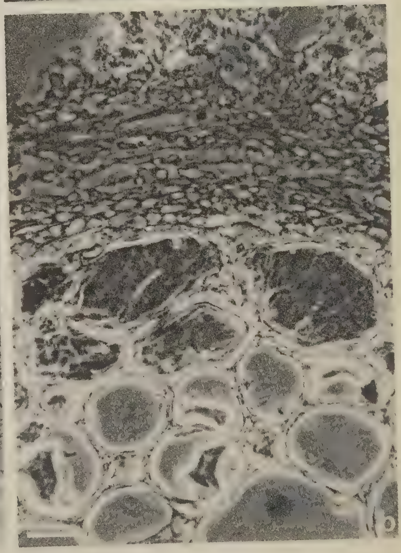
Pl. 4 - Lactarius picinus - a: Inner surface of mantle. - b: Cross section. - c: Longitudinal section through the very tip. - d: Cross section. (All figs. from RA 10745 in Herb. R. Agerer). - Bar for all figs. 10 µm.

Pl. 3 - Lactarius picinus - a: Habit of mycorrhizae. - b: Autofluorescence of laticiferous hyphae (Blue-filter). - c: Rhizomorph, longitudinal section. - d: Surface view of laticiferous hyphae. - e: Rhizomorph, cross section. - f: Inner surface of mantle. (All figs. from RA 10745 in Herb. R. Agerer). - Bar 1 mm (fig. a), 10 µm (figs. b - f).




11




10

3. RUSSULA OCHROLEUCA (Pers.) Fr.

Fig. 7, 8, Pl. 5, 6.

MORPHOLOGICAL CHARACTERS

Ramification: monopodial; length of unramified ends: - 2,8 (3,2) mm; diameter of unramified ends: 0,33 - 0,46 mm; shape of unramified ends: more or less straight or only slightly bent; structure of surface: smooth but with dots and with some rhizomorphs.
Colour of unramified ends: yellowish or slightly yellowish-olive with striking, yellowish dots of small amorphous crystals; colour of tips: similar as the other parts but without the yellowish dots or with dots less conspicuous; colour of older parts: umber brown with slightly olive tint, yellowish dots not conspicuous or absent.

ANATOMICAL CHARACTERS OF SURFACE

OUTER SURFACE OF MANTLE
Structure: pseudoparenchymatous with angular cells in surface view; size of hyphal cells: on the average 8,3 cells cut in a square of 400 µm; thickness of cell walls: up to 1 µm; surface of the very tip: like the cells of the remaining surface but cells smaller, about 17 cells cut in a square of 400 µm.
RHIZOMORPHS
Shape in cross-section: more or less round; arrangement and diameter of hyphae: hyphae run more or less parallel including a very thick central hypha, central hypha 10 - 12 µm in diam., the other hyphae (1,5) 2 - 3 (4) µm in diam.; thickness of cell walls: central hyphae up to 0,5 (1,0) µm, remaining hyphae inconspicuously thickwalled; colour of hyphae: more or less colourless; septae: without clamp connections; anastomoses: rare, hyphae agglutinated.
EMANATING HYPHAE
Shape and diameter: (1,5) 2 - 3 µm in diam.;

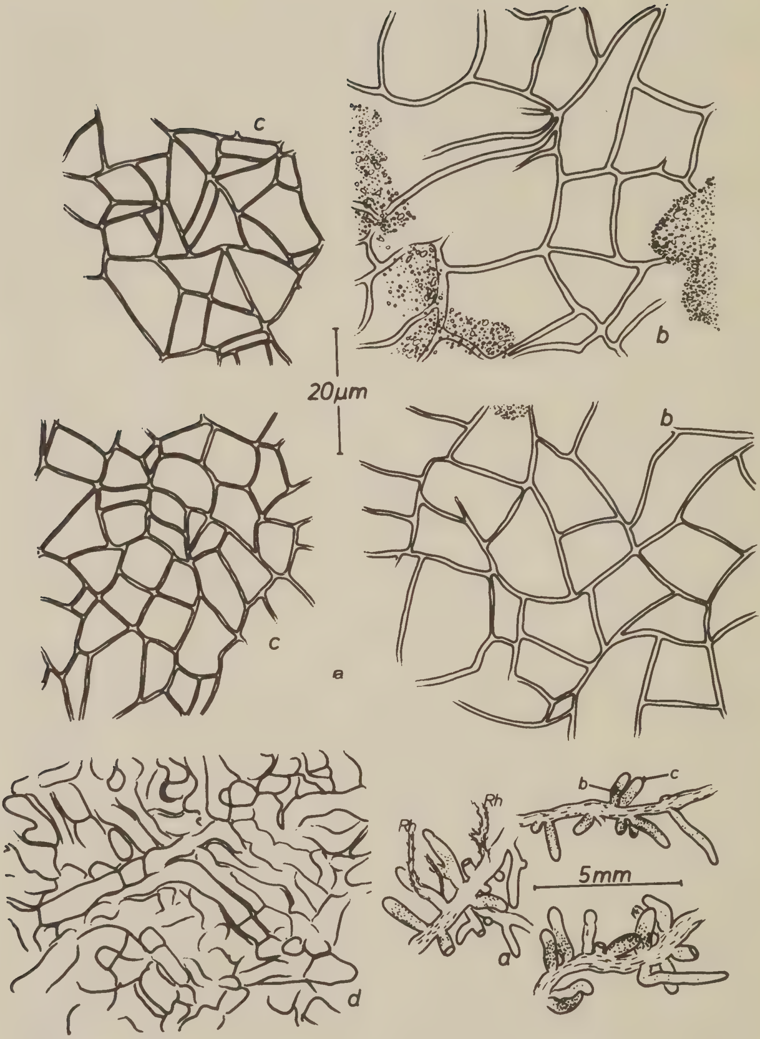


Fig. 7 - Russula ochroleuca - a: Habit of mycorrhizae. - b: Different surface views, with granular patches of yellow pigment. - c: Different surface views of the very tip. - d: Inner surface of mantle. (All figs. from RA 10705 in Herb. R. Agerer).

thickness of cell walls: up to 0,5 µm; colour of hyphae: more or less colourless; septae: without clamp connections.

CYSTIDIA none found.

INNER SURFACE OF MANTLE

Arrangement of hyphae: irregular; diametre of hyphae: 2 - 3 (4) µm, with short cells or cells somewhat longer.

ANATOMICAL CHARACTERS, CROSS-SECTION

MANTLE

Thickness and differentiation: 30 - 45 (50) µm, pseudoparenchymatous throughout, with raised spots; cell-shape and dimensions of different layers: cells of the outermost layer furnished partially with conical cell aggregates, mostly filled with small granula, cells tangentially 10 - 15 (20) µm, radially - 3,5 - 5,5 µm, outermost cellwall 0,5 - 1 µm thick, cells of the innermost layer roundish, 2 - 3 (5) µm in diam., remaining cells tangentially 10 - 15 (20) µm, radially - 5 - 9 µm.

TANNIN CELLS

Number of rows: 1 - 2, the inner layer less densely filled; shape and dimensions: flat and compressed, the outermost row shorter than the inner row, outer row - 30 - 55 (70) x 6 - 11 µm, the innermost row - 20 - 35 (40) x 9 - 20 µm.

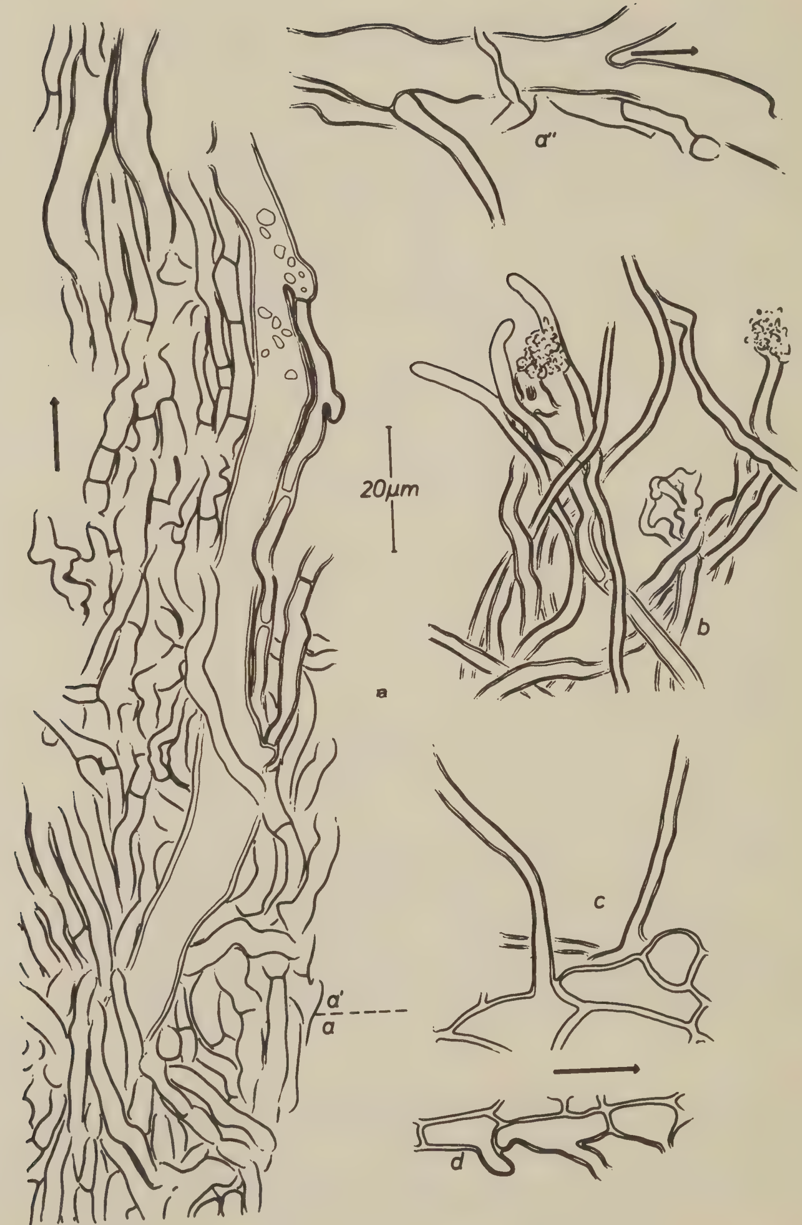
HARTIG NET

Shape and dimensions of cortex cells: round or slightly tangentially oval, 20 - 35 (60) x 15 - 25 (35) µm; depth of H'net: 4 - 5 rows of cortex cells; thickness of H'net: 2,5 - 3,5 (4) µm; number of hyphal rows of H'net: 1; shape of H'net cells in section: angular or slightly round, quadratic or rectangular.

ANATOMICAL CHARACTERS, LONGITUDINAL SECTION

MANTLE

Shape and dimensions of the very tip: almost regularly rectangular like a stone-wall, outermost layer 5 - 9 x 2,5 - 3 µm, innermost layer round to quadratic ca. 2 µm in diam., remaining cells 5 - 9


a''
20µm
b
a
c
a'
a
d

x (2,5) 3 - 4 (5,5) µm, surface furnished with the same conical cell-aggregates as mentioned for the cross-section.

HARTIG NET

Shape and dimensions of cortex cells: flat-rhomic, (40) 60 - 80 (100) x (15) 20 - 25 µm; shape and dimensions of tannin cells: oriented in a oblique way to inside backwards, (40) 50 - 80 (100) x (6) 8 - 12 (16) µm.

COLOUR REACTION IN DIFFERENT REAGENTS

Acetic-Fuchsin: salmon-red; a-Naphtol: ----; Ammonium-Hydroxide: ----; Brilliant-Kresyl-Blue: bright blue after treatment with water violet blue; Chlorazol-Black E: greyish-green; Cotton-Blue: walls slightly blue; Erythrosin: slightly pink; Fast-Green: yellowish-green; Gujak: ----; Iron-Sulfate: ----; KOH 15%: conspicuously ochre; Kongo-Red: slightly orange; Magnesium-Acetate: ---; Malachit-Green: greenish; Martius-Yellow: ---; Melzer's Reagent: ---; Phenol: dirty yellowish-geen; Phenol-Anilin: ----; Phloxin B: ---; Stahl's EP-Reagent: slightly ochre; Sulfo-Vanillin: ----; Toluidin-Blue: violet blue .

AUTOFLUORESCENCE

WHOLE MYKORRHIZA

UV 254 nm: ----; UV 366 nm: ----.

MANTLE AND RHIZOMORPHS

UV-filter 340 - 380 nm: slightly yellowish-green; BLUE-filter 450 - 490 nm: distinctly yellowish-green.

Fig. 8 - *Russula ochroleuca* - a: Rhizomorph in surface view. - a': Squashed rhizomorph with free central, thick hypha. - a'': Ramified central hypha of rhizomorph. - b: Emanating hyphae of mycorrhiza. - c, d: Bases of emanating hyphae, c in tangential view, d in longitudinal section. (All figs. from RA 10705 in Herb. R. Agerer).

STAINING OF NUCLEI

Cells of mantle and emanating hyphae with two nuclei, lying close together (Method: aceto-carmine).
Siderophilous reaction negative.

MATERIAL STUDIED AND METHOD OF IDENTIFICATION

Germany, Bavaria, zwischen Odelzhausen und Mering, im Höglwald, 19. 9. 1984, with Picea abies; reference specimen of mycorrhiza and fruitbody in Herb. RA 10705 in Herb. R. Agerer. There were connections between the stipe of the fruitbody and the mycorrhiza.

COMPARISON OF THE MYCORRHIZA OF RUSSULA OCHROLEUCA WITH THOSE OF R. XERAMPELINA

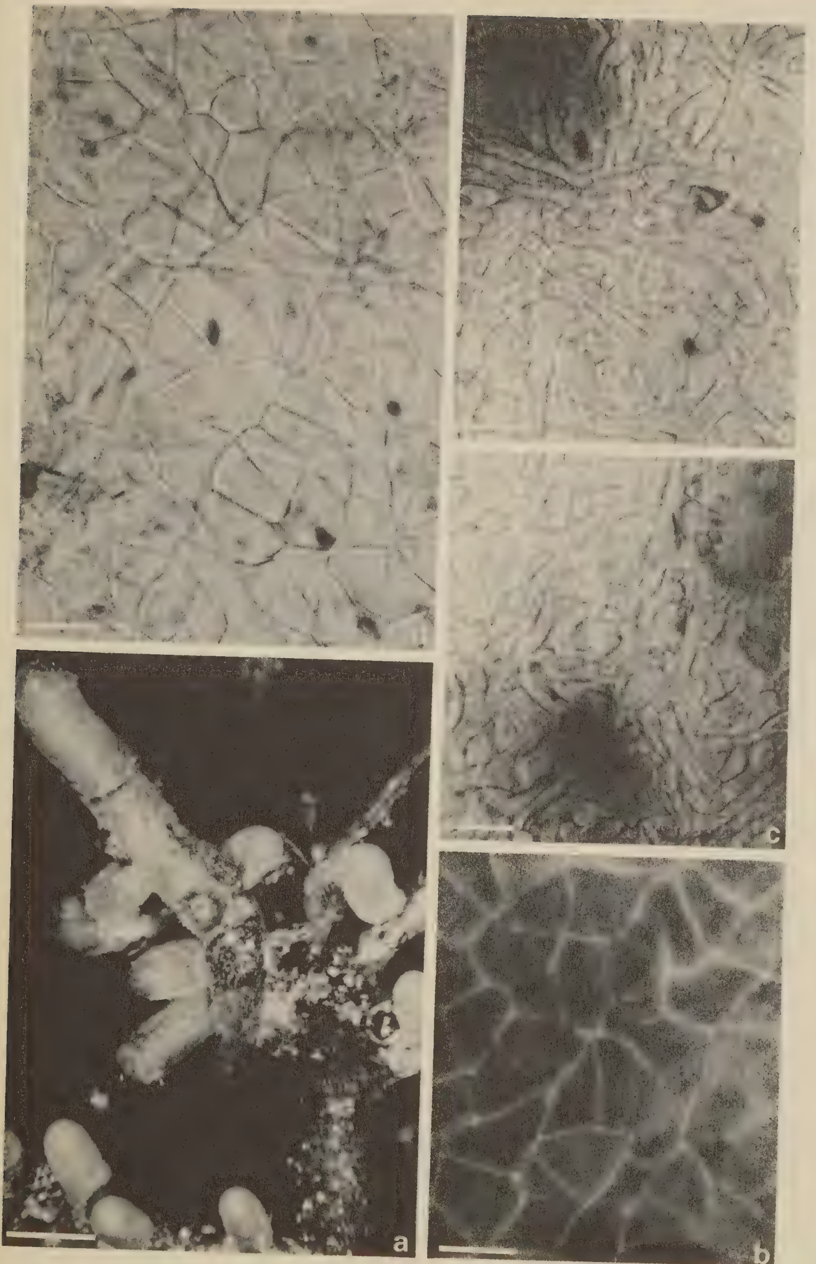
(Selected features only)

(1) Morphological characters

A very conspicuous difference between these two species concerns the colour of the mycorrhizae. The mycorrhizae of Russula ochroleuca are always furnished with striking yellowish dots made up of conical cell-aggregates and granular substances, which may lay upon the cell walls; very often the cells of the conical cell-aggregates are filled with granules which may cause the yellow colour, too. Similar encrusting pigments are present on the hyphae of the cap surface of fruitbodies. This is the reason why the colour of the mycorrhiza is similar to the colour

---

Pl. 5 - Russula ochroleuca - a: Habit of mycorrhizae. - b: Autofluorescence of mantle surface (Blue-filter). - c, e: Inner surface of mantle. - d: Surface view of mantle. (All figs. from RA 10705 in Herb. R. Agerer). - Bar 1 mm (fig. a), 10 µm (figs. b - e).


c
a
b

of the fruitbody. The same is recognizable in R. xerampelina, though there are obviously no encrusting pigments on the mantel surface, the dark fleshy-brown appearence is reminiscent of the less intensively coloured parts of the fruitbody of R. xerampelina.

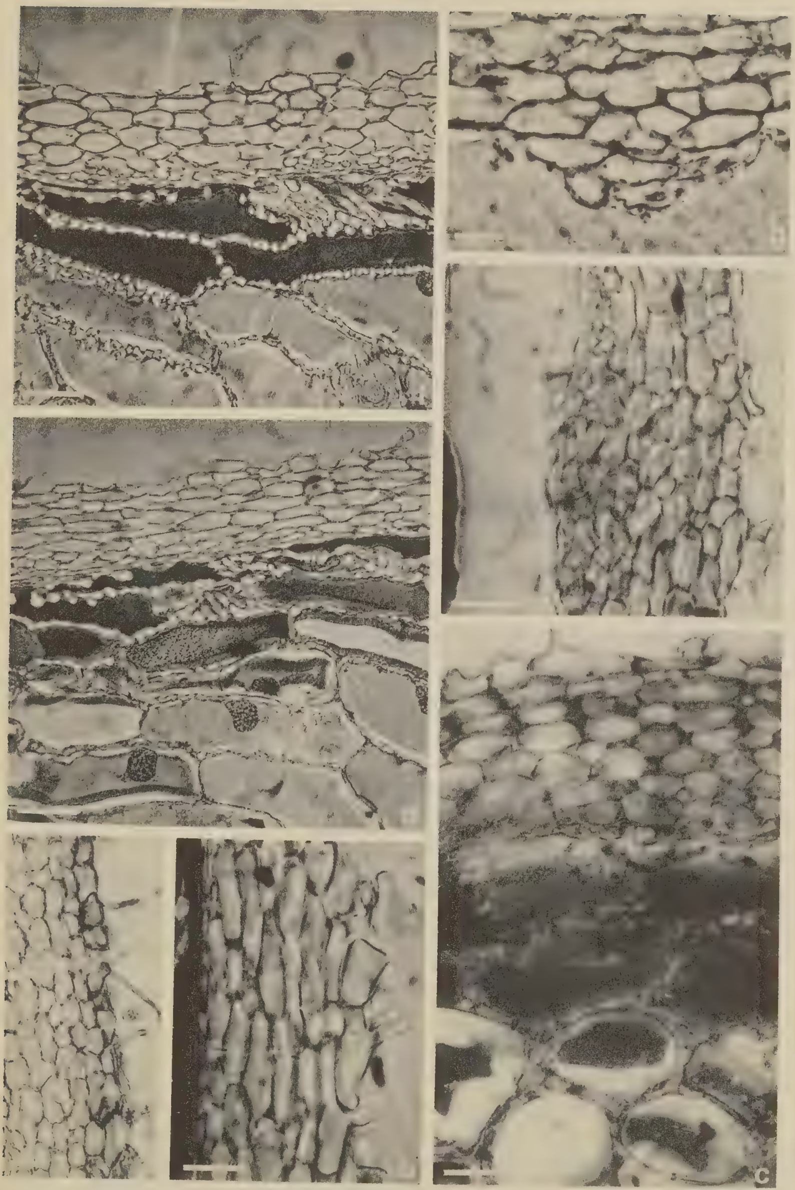
The most striking differences occur once more in the structure of mantles. The mantle surface of R. ochroleuca shows a typical pseudoparenchyma with angular cells furnished with the conical cell-aggregates, whereas R. xerampelina possesses a more or less dense network of strongly anastomosing hyphae. Only the mantle of R. xerampelina shows typical cystidia as known in the genus Russula (ROMAGNESI 1967). R. ochroleuca seems to produce thicker mantles than R. xerampelina . The rhizomorphs, however, belong to the same type with centrally arranged voluminous hyphae. It is probably not of great significance that there are a lot of such thick hyphae in R. xerampelina but only a single one or a few in R. ochroleuca. The central hyphae of the rhizomorphs of R. ochroleuca seem to be thicker than those of R. xerampelina.

(2) Characterization after treatment with different reagents

Many differences could be found, but some are not distinctive enough to differentiate the two species. The most conspicuous are the following. Chlorazol-black E makes the mantle of R. ochroleuca mycorrhizae greyish-green whereas it turns the mantle of R. xerampelina greyish-blue. The mantle of R. ochroleuca becomes distinctly ochraceous after treatment with KOH whereas the mycorrhiza of R. xerampelina does not show this

---

Pl. 6 - Russula ochroleuca - a, b: Emanating hyphae (longitutinal section). - c: Cross section. - d: Longitudinal section, somewhat more distant from very tip than fig. f. - e: Longitudinal section through very tip. - f: Longitudinal section, behind the very tip. - g: Longitudinal section, mantle with conical cell aggregates. (All figs. from RA 10705 in Herb. R. Agerer). - Bar for all figs. 10 µm.


C

reaction. In Phenol the mycorrhiza of R. ochroleuca becomes dirty yellowish-green, while that of R. xerampelina shows no reaction. A further difference regarding treatment with Phenol is that after washing of the tinged mantle with water the mantle of R. xerampelina alone becomes slightly umber-brown. Phloxin B causes the mantle of the R. xerampelina mycorrhiza to show a slightly red reaction. Stahl's EP reagent, however, turns the mantle of R. ochroleuca exclusively into a slighty ochre colour. Only in R. xerampelina were the inner hyphae of mantle tinged distinctly red with Sulfo-Vanillin. In R. xerampelina ROMAGNESI (1967) remarks that there is no reaction with Sulfo-Vanillin. Only insignificant differences could be recognized after treatment with Cotton-blue: the hyphae of R. xerampelina become darker than those of R. ochroleuca. ROMAGNESI (1967) obtained a purplish colour after having treated the yellowish encrusted hyphae of the cap of R. ochroeuca with acetic-fuchsin, a salmon red tinge was produced in our ivestigations of the mycorrhiza of R. ochroleuca. The mantle of R. xerampelina, however, showed a similar reaction with acetic-fuchsin to that of R. ochroleuca. SCHÄFFER (1952) mentioned an olive reaction of the fruitbodies of R. xerampelina with iron-sulfate, which did not correspond with our results on the mycorrhizae of this species. According to SCHÄFFER Russula ochroleuca shows an indish-red reaction wih Phenol, but the mantle of the mycorrhizae became dirty yellowish-green with this reagent. These differences between the reactions of fruitbodies and mycorrhizae may well be caused by storage of the mycorrhizae.

(3) Siderophilous granula

Russula xerampelina is so far the only species of Russula with siderophilous reactions of parts of the mycorrhizal mantle. No such reaction is known in parts of the fruitbodies.

MYCORRHIZA OF RUSSULA OCHROLEUCA AS TREATED IN LITERATURE

There is not a single mycorrhiza known of the species of the section Ingratae of the genus Russula.

4. RUSSULA XERAMPELINA (Schff. ex Secr.) Fr.

Fig: 9, 10, Pl. 7, 8.

MORPHOLOGICAL CHARACTERS

Ramification: monopodial; length of unramified ends: up to 2 mm; diameter of unramified ends: (0,24) 0,33 - 0,39 (0,48) mm; shape of unramified ends: more or less straight; structure of surface: smooth, with some rhizomorphs.
Colour of unramified ends: dark flesh-brown, lustreless; colour of tips: somewhat paler,lustrous; colour of older parts: dark reddish brown, lustrous.

ANATOMICAL CHARACTERS OF SURFACE

OUTER SURFACE OF MANTLE
Structure: losely woven, like a net of strongly anastomosing hyphae; size of hyphal cells: (4) 5 - 7 µm; thickness of cell walls: up to 1 µm; surface of the very tip: hyphae conspicuous, short, densely plectenchymatous or slightly pseudoparenchymatous.
RHIZOMORPHS
Shape in cross-section: more or less round; arrangement and diameter of hyphae: central hyphae thick, 7 - 9 µm, remaining hyphae 2,5 - 5 µm; thickness of cell walls: walls of central hyphae ca. 1 µm, joining hyphae only sligtly thick walled, hyphae towards the margin up to (0,5) 1 µm; colour of hyphae: more or less colourless, septae: clampless; anastomoses: rare.
EMANATING HYPHAE
Shape and diameter: probably only proximally ramified, 1,5 - 2 µm; thickness of cell walls: only slightly thick-walled, thinner than 0,3 µm; colour of hyphae: more or less colourless; septae: clampless.
CYSTIDIA rare, somewhat subulate, 30 - 40 x 5 - 6 µm (proximal).
INNER SURFACE OF MANTLE
Arrangement of hyphae: irregular, sometimes

coiled, hyphae densely woven, agglutinated; diametre of hyphae: 2,5 - 3 µm.

ANATOMICAL CHARACTERS, CROSS-SECTION

MANTLE

Thickness and differentiation: 20 - 30 µm, pseudoparenchymatous throughout; cell-shape and dimensions of different layers: outermost hyphal layer losely woven, tangentially (2) 6 - 10 (14) µm, radially 2 - 2,5 µm, only slightly thick-walled, innermost layer with more or less round cells, 2 - 3 µm in diam., remaining cells more or less round or slightly tangentially elongated, tangentially (2) 5 - 9 (15) µm, radially (2) 3 - 4 (5) µm.

TANNIN CELLS

Number of rows: 2 (-3); shape and dimensions: irregularly shaped, tangentially-slender, outermost row 50 - 65 x 2 - 87 (20) µm, joining row (35) 45 - 60 (70) x 8 - 15 µm.

HARTIG NET

Shape and dimensions of cortex cells: oval, slightly radially elongated, (20) 27 - 35 x 10 - 20 µm; deepness of H'net: 4 - 5 rows neighbouring to the endodermis; thickness of H'net: 3 - 4 µm; number of hyphal rows of H'net: 1 (between tannin cells up to 2 (3) rows); shape of H'net cells in section: often elongated, but cells of the outer cortex layer mostly more or less round.

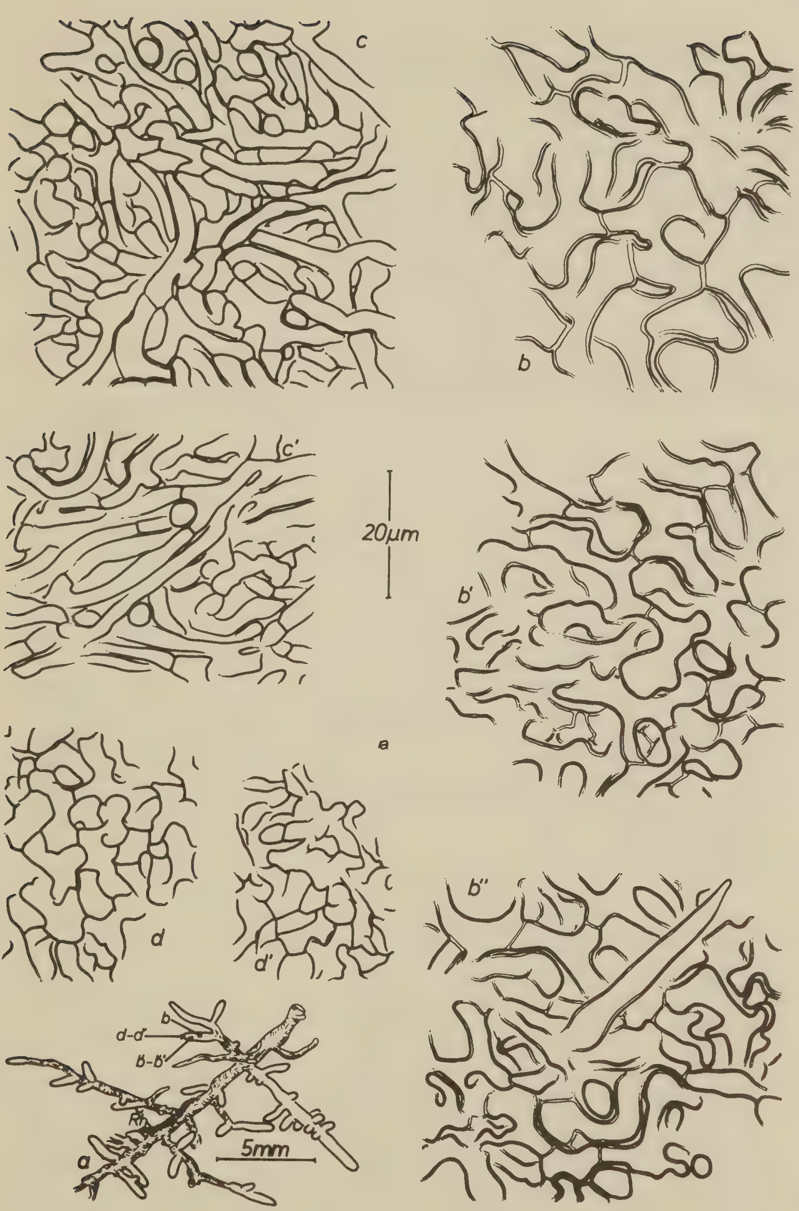
ANATOMICAL CHARACTERS, LONGITUDINAL SECTION

MANTLE

Shape and dimension of the very tip: pseudoparenchymatous, with smaller cells, without distinct layers, tangentially 3 - 5 µm, radially

---

Fig. 9 - Russula xerampelina - a: Habit of mycorrhizae. - b, b', b'': Different surface views. - c, c': Different views of inner mantle surface. - d, d': Different views of the very tip. (All figs. from RA 10725 in Herb. R. Agerer).


c
b
c'
20µm
b'
a
d
d'
b''
b
d-d'
b-b'
Rh
5mm
a
So

2 - 3 µm; shape and dimensions of cells in different layers: outermost cells tangentially 6 - 10 (15) µm, radially 2 - 4 µm, innermost layer tangentially 3 - 8 x 2 - 3 µm, remaining cells 5 - 15 x 3 - 6 (8) µm.

HARTIG NET

Shape and dimensions of cortex cells: elongated, oriented in an oblique way to inside backwards, (30) 40 -60 (80) x (12) 15 - 22 (28) µm; shape and dimensions of tannin cells: elongated like cortex cells, 30 - 60 (80) x 4 - 10 µm.

COLOUR REACTION IN DIFFERENT REAGENTS

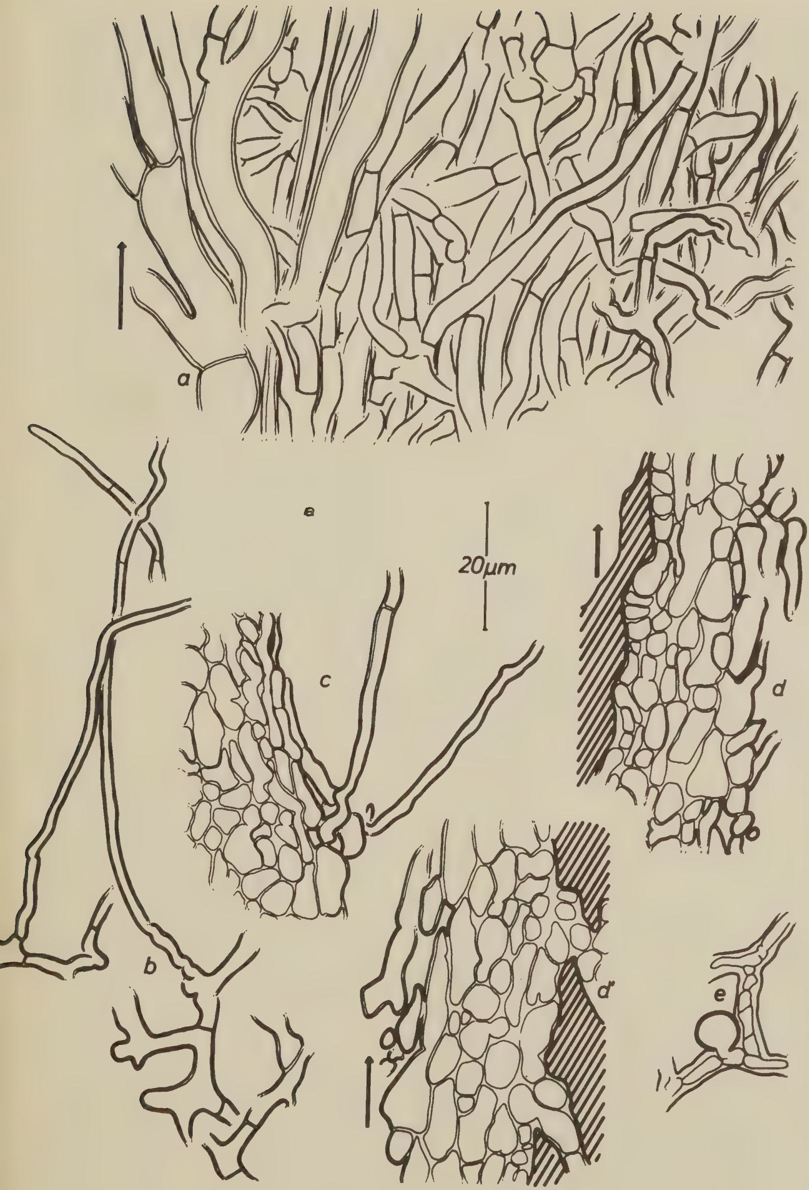
Acetic-Fuchsin: slightly reddish; a-Naphtol: ----; Ammonium-Hydroxide: ----; Brilliant-Kresyl-Blue: bright blue, after treatment with water violet blue; Chlorazol-Black E: greyish-blue; Cotton-Blue: hyphal walls distinctly blue; Erythrosin: slightly red; Fast-Green: green; Gujak: ----; Iron-Sulfate: ----; KOH 15%: ----; Kongo-Red: slightly red; Magnesium-Acetate: ----; Malachit-Green: green; Martius-Yellow: ----; Melzer's Reagent: ----; Phenol: ----, but after treatment with water slightly umbre-brown; Phenol-Anilin: ----; Phloxin B: slightly red; Stahl's EP-Reagent: ----; Sulfo-Vanillin: hyphae of inner surface of mantle distinctly pink, the other hyphae only pinkish; Toluidin-Blue: violet blue.

AUTOFLUORESCENCE

WHOLE MYKORRHIZA

UV 254 nm: ----; UV 366 nm: ----.

Fig. 10 - Russula xerampelina - a: Optical section through rhizomorph running along rootlet. - b: Emanating hyphae of mycorrhiza. - c: Emanating hyphae (cross section of mycorrhiza). - d, d': Longitudinal section (mantle). - e: Hartig net with balloon like structure (cross section). (All figs. from RA 10725 in Herb. R. Agerer).


a
a
20µm
b
c
d
d'
e

MANTLE AND RHIZOMORPHS
UV-filter 340 - 380 nm: slightly blue; BLUE-filter 450 - 490 nm: distinctly greenish-yellow.

STAINING OF NUCLEI

Cells of the inner mantle hyphae, of emanating hyphae and cells of the hyphal net on the outer surface had two nuclei lying mostly close together (method: acetic-carmine). - The siderophilous reaction was positive in some of the outermost hyphae of the mycorrhizal surface.

MATERIAL STUDIED AND METHOD OF IDENTIFICATION

Germany, Bavaria, München-Oberschleißheim, Korbiniani-Hölzl, bei Versuchsfläche O, 22. 9. 1984, reference specimen of mycorrhiza and fruitbody RA 10725 in Herb. R. Agerer; with Picea abies. The Mykorrhiza was overgrown by the stipe of the fruitbody.

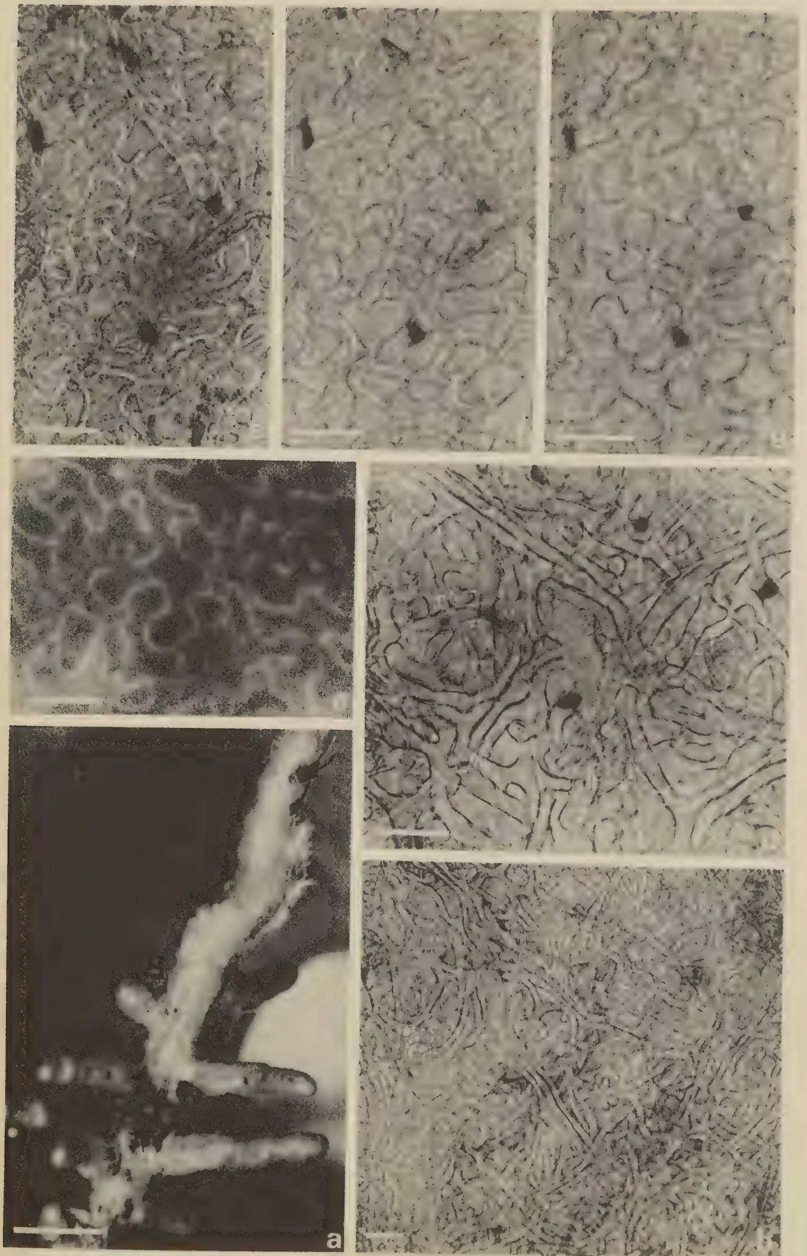
COMPARISON OF THE MYCORRHIZAE OF RUSSULA XERAMPELINA WITH THOSE OF R. OCHROLEUCA

(See comments on R. ochroleuca)

MYCORRHIZAE OF RUSSULA XERAMPELINA AS TREATED IN LITERATURE

Out of the section Rigidae of the genus Russula only the mycorrhizae of Russula vesca and R. grisea are known. MODESS (1941) tried to obtain R. xerampelina in culture but he was not successful.

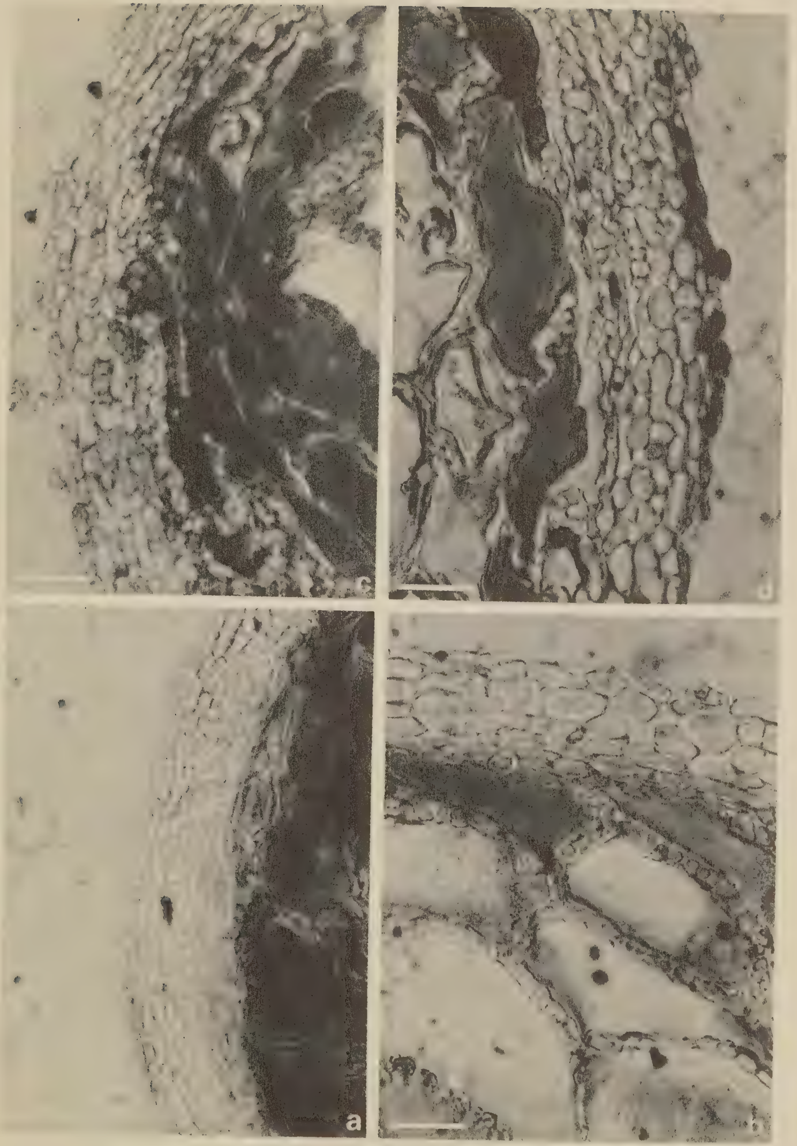
Pl. 7 - Russula xerampelina - a: Habit of mycorrhizae. - b, d: Inner surface of mantle. - c: Autofluorescence of inner layers of mantle. - e - g: Surface views in three different focus' from one and the same point: e = outermost, f = joining layer, g = a little more deeper. (All figs. from RA 10725 in Herb. R. Agerer). - Bar 1 mm (fig. a), 10 µm (figs. b - g).


a

CERUTI & BUSSETTI (1962) described and illustrated with half schematic line drawings the mycorrhiza of R. grisea + Tilia tomentosa. A striking feature are the pear-shaped cystidia and a dense indument of emanating hyphae on the mantle surface. The brightly coloured sulfur-yellow mycorrhiza and the light yellow colour of the mantle distinguish this mycorrhiza very well from that of R. xerampelina, too. The structure of the mantle should be prosenchymatic. Further essential characteristics are not mentioned.

LUPPI & GAUTERO (1967) described and drew what is probably the mycorrhiza of R. vesca. The mantle is pseudoparenchymatous at some points plectenchymatous at others. In this feature the mycorrhiza of R. cf. vesca seems to be similar to that of R. xerampelina. The authors, however, showed no surface view of the mantle and the similarity is therefore not obvious. The colour of the mycorrhiza characterized by LUPPI & GAUTERO is cream or light hazel-brown and thus deviates from that of the mycorrhiza of R. xerampelina. The emanating hyphae of these two species look similar.

Pl. 8 - Russula xerampelina - a: Longitudinal section through the very tip. - b: Longitudinal section. - c: Cross section near the very tip. - d: Cross section. (All figs. from RA 10725 in Herb. R. Agerer). - Bar for all figs. 10 µm.


c
d
a
b

III DISCUSSION

1. Discussion of the features used for characterization

a. Surface views (inner and outer) of mantle

This feature was first used by GIBELLI (1883) and FRANK (1885). GIBELLI characterized some mycorrhizae by line drawings of their surface. His studies show remarkable details of structure. He studied mycorrhizae of different host trees: *Quercus, Corylus, Ostrya, Carpinus.* FRANK (1885) described mycorrhizae of *Carpinus betulus* and of *Fagus silvatica.* He showed three characteristic surface views: one showing a plectenchymatous structure with many emanating hyphae, another a plectenchymatous view with few emanating hyphae, and a third of a smooth mycorrhiza with pseudoparenchymatous surface and without emanating hyphae. MANGIN (1910) also used the surface view characteristics when he described the mycorrhiza of *Fagus silvatica* and showed a line drawing of it. Unfortunately the feature of surface view of ectomycorrhizae was forgotten or not taken into account until CHILVERS (1968) used it for the description of *Eucalyptus* mycorrhizae. He showed remarkable differences in this characteristic and documented this with exact line drawings. Because of the consequent usage of the surface views the study by CHILVERS is one of the most important and most instructive publications concerning characterization of ectomycorrhizae. ZAK (1969) used the surface view to characterize the mycorrhiza of *Poria terrestris* + *Pseudotsuga menziesii.* However, for characterizing the mycorrhiza of *Rhizopogon vinicolor* + *Pseudotsuga menziesii* ZAK (1971) and for *Byssoporia terrestris* + *Pseudotsuga menziesii* (ZAK & LARSEN 1978) ZAK renounced the use of this feature with. VOIRY (1981) too, did not show mantle surface views. He, however, used tangential sections through the mycorrhiza as did some other investigators. Such sections may show some important features too, but they are mostly not as characteristic as are direct views of the surface (this is well demonstrated by the photographs of different levels of focus of the mycorrhizae of *Russula*

xerampelina, see plt. 7). ALEXANDER (1981) again used this feature for characterizing the mycorrhiza of Lactarius rufus + Picea sitchensis; he applied an interference contrast microscope to demonstrate the epidermoid structure of this smooth mycorrhiza. Thus he was able to get a more impressive view. PALM & STEWART (1984) depicted the surface view of only one of their characterized mycorrhizae of some Suillus species. Even Godbout & Fortin (1985a) did no show the surface views of the synthesized mycorrhizae with Populus tremuloides and they "felt that this is an informaton gap". In future, however, they will use tangential views and rhizomorphal structures as CHILVERS (1968) has done.
Currently, scanning electron microscope is more often used. But it seems to be of limited value, because it does not show advanced features. And a SEM is unsuitable for determining of mycorrhizae. In addition light microscopy shows features of septation of hyphae. In relation to the structure of crystals which may sheath the hyphae, however, SEM may be very useful (THOMAS & JACKSON 1982). The same is true for ontogenetic studies (PICHE et al. 1983). The development of the mantle was researched by SEM very successfully for example by STRULLU (1973, 1979) and SEVIOUR et al. (1978). It appears that ZAK (1969) and PALM & STEWART (1984) are the only who studied and described the inner surface of the mycorrhizal mantle. ZAK was able to demonstrate that this view may show some instructive details. The innermost layer of Byssoporia terrestris + Pseudotsuga menziesii possessed stellate arrangement of hyphae. In our researches on further mycorrhizae we found similar structures (AGERER, in preparation).

Another advantage of surface view is that it enables examination of the structure of laticiferous hyphae of mycorrhizae of deeper layers of the mantle. Such features were used successfully by LUPPI & GAUTERO (1967) and VOIRY (1981).

b. Rhizomorphs

In the literature several terms have been employed to describe these structures. For example, rhizomorph, hyphal bundle, and hyphal strand. The term rhizomorph is mostly used for compactly packed hyphae running more or less parallel whereas hyphal bundle or strand is used if hyphae are more or less loosely connected by different mechanisms, e. g. anastomoses or twirling around. Because a continuum can be demonstrated (AGERER, in prep.) between the two extremes we use exclusively the term rhizomorph when hyphae are connected and grow more or less parallel and more or less close together for a greater distance.

Again it was CHILVERS (1968) who used the features of the rhizomorphs consequently to describe a number of mycorrhizae. The variety of organization of rhizomorphs is impressive. Besides the mantle view this structure may help a great deal to differentiate between mycorrhizal types, as for example in the case of mycorrhizae of Lactarius deterrimus, L. picinus, Russula ochroleuca and R. xerampelina.

The rhizomorphs are likely to be physiologically important for the so-called smooth mycorrhizae known especially within the genera Lactarius and Russula (FROIDEVAUX 1973, LUPPI & GAUTERO 1967, MELIN 1924, OGAWA 1981, RIFFLE 1973, VOIRY 1981). Because usually very few emanating hyphae are present, the transport of water must occur principally within the rhizomorphs. There exist different types of rhizomorphs even in one genus (see Lactarius deterrimus and L. picinus). Our results do not concur with those of GODBOUT & FORTIN (1985) who characterized the mycorrhizae of Lactarius and Russla as being without strands (rhizomorphs). All mycorrhizae of these two genera which we have examined so far (AGERER, in prep. BRAND & AGERER in prep., GRONBACH & AGERER in prep.) showed typical rhizomorphs.

It seems that where rhizomorphs could not be found they may have been lost in the extraction and cleaning process. It is unlikely that the sparse emanating hyphae are effective enough to nourish the mycorrhizae and the tree. Comparing mycorrhizae from soil and those grown by synthesizing ALEXANDER (1981) remarked for Lactarius rufus that in nature he had never found rhizomorphs whereas they appeared on the synthesized mycorrhizae. The supposition that rhizomorphs are probably present and lost only by washing is supported by AGERER (1985) who made it probable that the mycorrhizae of the genera Lactarius and Russula belong to the most effective ones for water transport. And this would not be understandable for mycorrhizae without rhizomorphs or without enough effective emanating hyphae.

MASUI (1926a) stated for an unidentified mycorrhiza that old ones in contrast to young mycorrhizae always produce hyphal bundles or filaments. Therefore one must additionally take into account that the presence or absence of rhizomorphs could be depending on the age of mycorrhizae.

Features of the rhizomorphs were used for delimiting types of mycorrhizae by VOIRY (1981), but unfortunately no details of the rhizomorph structures were given.

In the early twenties MASUI (1926b) observed hyphal bundles on a Quercus mycorrhiza and showed a cross section through a rhizomorph which he believed belonged to Suillus luteus. For the fungs he demonstrated thick centrally arranged hyphae. In the same year (MASUI 1926a) MASUI described and showed with line drawings some rhizomorphs of different mycorrhizae. They were partially differentiated into centrally thicker hyphae and diverging thinner ones. MASUI (1926, 1927) figured the morphology of some smooth mycorrhizae possessing rhizomorphs without characterizing them microscopically. MELIN (1923) provides line drawings of a rhizomorph with distinctly thick, voluminous central hyphae surrounded by thin parallelly running hyphae, otherwise he only described or depicted the gross morphology of rhizomorphs.

ZAK (1969) compared microscopically the rhizomorphs of Byssoporia terrestris (var. sartoryi and var. aurantiaca) and was able to show distinct differences in the organization of the hyphae. One rhizomorph possessed more or less parallel hyphae whereas the other was built of irregularly interwoven hyphae. The rhizomorphs of Rhizopogon vinicolor + Pseudotsuga menziesii mycorrhizae were also described anatomically by ZAK (1971). In comparison with those of B. terrestris there were distinct differences.

Rhizopogon vinicolor produced rhizomorphs with centrally arranged thick hyphae. Again ZAK (ZAK & LARSEN 1978) analyzed microscopically the structure of rhizomorphs of some additional varieties of Byssoporia terrestris. These rhizomorphs showed striking differences from those of the at first mentioned varieties (ZAK 1969) of this species. These examples make it obvious that the features of rhizomorphs are as useful as those of the surface views for characterization of ectomycorrhizae. The taxonomic importance of the rhizomorphs was already stressed by ZAK (1973). PALM & STEWART (1984) described the mycorrhizae of some Suillus species and showed rhizomorphs. Microscopical descriptions of the rhizomorphs, however, are absent.

Recent investigations on organization and function of rhizomorphs were carried out by FOSTER (1981) and DUDDRIDGE et al. (1980).

c. Cross- and longitudinal sections, emanating hyphae and cystidia

These features were applied by DOMINIK (1969) for characterizing various mycorrhizae and for constructing a key. Since DOMINIK these characteristics have very often been successfully used. Organization of mantle (prosenchymatous, pseudoparenchymatous), type of cystidia, features of the emanating hyphae (colour, thickness of walls, clamps, diameter a.s.o.) are all suitable to describe mycorrhizae.

In our investigation only one type of cystidia occurred (a typical one of the genus Russula in R. xerampelina mycorrhiza), emanating hyphae are very scanty.

Longitudinal sections have seldom been investigated. LUPPI & GAUTERO (1967) described different mycorrhizae showing only longitudinal sections. Whereas MASUI (1926a, 1926b, 1927) and CHILVERS (1968) applied cross- and longitudinal sections for describing mycorrhizae.

We were able to point out that longitudinal sections are important for characterizing the mycorrhizae, because the structure of the mantle may vary from the very tip to its proximal parts (see R. ochroleuca, pl. 6).

d. Reactions with different chemicals

ZAK (1973) reviewed the publications which have dealt with colour reactions of mycorrhizae with different reagents up to 1973.

With the aid of chemical reagents FROIDEVAUX (1973) compared the mycorrhiza of Lactarius obscuratus with the basal mycelium of the fruitbodies; he used eight different reagents (Iron-sulfate, Sulfuric acid, KOH 15%, Ammonium-hydroxide, Chlorovanillin, Guaiacol, Pyrogallol, Sulfoformol) and he was able to show corresponding colour changes.

MISHRA & SHARMA (1981) compared with the aid of chemical reagents mycorrhizae with associated fruitbodies. They used five different reagents (Iron-sulfate, Sulfuric acid, Ammonium-hydroxide, KOH (15%) and Melzer's reagent). They found on the one hand differences between species of mycorrhizae and on the other between mycorrhizae, rhizomorphs and fruitbodies of one and the same species.

In our present studies of ectomycorrhizae we used a set of chemicals comprising now 22 different reagents. These chemicals are already applied to about four dozen still undescribed mycorrhizae. And it seems that some of these reagents cause in all mycorrhizae the same colour changes, for example fast-green and malachit-green. It is possible that therefore some of them will not be applied further. Other reagents will be added. It is the aim to get a suitable set of reagents to characterize mycorrhizae on a chemical basis.

e. Autofluorescence

TRAPPE (1967) and ZAK (1973) proposed to use the autofluorescence of mycorrhizae at different wave lengths. This approach was has been used rather rarely although some mycologists use it for characterizing relationships of fungi (MOSER 1978, subgenus Leprocybe of genus Cortinarius). Fluorescence microscopic has been used even less often. ZAK (1971) studied the autofluorescence of the whole mycorrhiza of Rhizopogon vinicolor, FROIDEVAUX (1973) that of pieces of mantle of Lactarius obscuratus mycorrhizae. The differences revealed between the four mycorrhizae in the present study using this method are not exciting, but further studies (AGERER, in prep.) have already shown that there are striking differences in the behaviour regarding autofluorescence.

f. Staining of nuclei and siderophilous granulation.

Up to now the siderophilous granulation has not been used for characterization of mycorrhizae but this characteristic has been widely applied by fruitbody taxonomists (e.g. CLEMENCON 1978). As has been shown, the mycorrhizae of *Russula xerampelina* possess siderophilous granula in some of the hyphae of the mantle surface; this character will be studied in further investigations. CLEMENCON (1978) noted for *Russula fragilis, R. sardonia* and *R. adusta* and for *Lactarius maculatus* and *L. griseus* small siderophilous granula in the basidia; *Russula ochroleuca, R. xerampelina, Lactarius deterrimus* and *L. picinus* have probably not been studied yet in this regard.

Nuclear staining reactions provide the opportunity to distinguish between mycorrhizae produced by ascomycetes and by clampless basidiomycetes. All mycorrhizae without clamps examined up to now have mostly had cells with two nuclei. It may be important to know, whether the nuclei lie close together or not (AGERER, in prep.).

g. Shape and colour

ZAK (1973) reviewed the value of colour and form in mycorrhizae. PALM & STEWART (1984) were able to stress differences in the shape of *Suillus* mycorrhizae. They could categorize the mycorrhizae in terms of the mode of branching and the arrangement of branches.

The shape of the presently treated mycorrhizae is relatively uniform, and the pyramidal shape of the mycorrhizae of *Lactarius picinus* can be considered merely as a somewhat denser ramification arising from a pinnate arrangement. The colours of the characterized mycorrhizae are typical and distinct. The variability of colour is stressed by the mycorrhiza of Lactarius deterrimus which changes the colour with increasing age from bright copper orange to dark olive. A fact which is described by ZAK (1973) for the mycorrhiza of Lactarius sanguifluus + Pseudotsuga menziesii.

2. Methods of identification

Syntheses experiments have the disadvantage that it is not possible to simulate natural conditions for the fungi or for the tree. Some publications make it obvious that there are alterations of mycorrhizal types with ageing of trees (e.g. CHU-CHOU 1979, FLEMING et al. 1984). And therefore it could be quite possible that the influence of the youth of tree-seedlings may be great enough to change some features of the mycorrhizae compared with those of mycorrhizae known from old trees. There are some other known effects on the structure of mycorrhizae. DUDDRIDGE & READ (1984) have shown the influence of sugar within the nutrient solution for the development of mycorrhizae and were able to detect distinct alterations in the area of mantle and Hartig net. The influence of pH was already shown by MELIN (1924a) and was stressed by MOSSE et. al. (1981). The importance of nutritional factors was demonstrated e. g. by MEYER (1985) very recently. Some other factors may play an important role in the formation of mycorrhizal structures such as light intensity and age of the fungal inoculum.

Although MELIN (1959) stressed that the mycorrhizae synthesized by him had the same appearance and the same anatomical features compared with those isolated form the soil, detailed comparisons of synthesized and natural mycorrhizae are very rare. Recently ALEXANDER (1981) compared synthesized and natural mycorrhizae of Lactarius rufus + Picea sitchensis and discovered some differences in the mode of ramification, in colour of mantle, in contents of hyphae and in shape of the tannin-layer. Probably these features are of less importance for characterizing mycorrhizae, but it must be considered that these may be morphological and anatomical differences which may become essential for delimiting species of mycorrhizae. The most important characteristic - the shape of cells of the mantle surface - however, remained quite identical. The rhizomorphs could not be compared by ALEXANDER because he could not find rhizomorphs on mycorrhizae formed in natural soil.

PACHLEWSKI (1968) ascertained that with respect to the method of synthesizing there may be striking differences in the structure of mycorrhizae. The mycorrhizae of *Rhizopogon luteolus*, formed in the air, possessed a distinctly hairy mantle with rhizomorphs (for possible explanation see HARLEY & SMITH 1983), whereas mycorrhizae grown in agar were smooth or only sporadically hairy. Differences in the cross sections of the mantle were noted too, by PACHLEWSKI. Hairy mantles were two-layered, while smooth mantles were undifferentiated. Although the differences between natural and aseptically grown mycorrhizae may not always be as great as under the extreme synthesizing conditions used by PACHLEWSKI, these facts stress the need for cautious interpretation of features seen in synthesized mycorrhizae. THOMAS & JACKSON (1979) also warn against relating aseptically synthesized mycorrhizae with those occurring in nature. LAIHO (1970), however, stated that in his researches on *Paxillus involutus* there were no differences recognizable between natural mycorrhizae and mycorrhizae synthesized under different conditions.

One of the most important questions is, how to recognize mycorrhizae found in natural soil. A decision about the identity of mycorrhizae is really possible if we look critically and patiently for unequivocal connections between mycorrhizae and fruitbodies. This is especially true if we can detect and follow distinct rhizomorphs. For those mycorrhizal fungi which cannot be cultured, this method is the one and the only possibility to identify mycorrhizae with certainty. If mycorrhizae were isolated from the soil one can be shure that all characteristics are natural in contrast to the features of the synthesized mycorrhizae which well may provide additional or changed features.

3. Variability of the species of mycorrhizae

Researches on the variability of ectomycorrhizae isolated from soil have not so far been concerned. This is not surprising, because the descriptions of unidentified mycorrhizae are mostly very poor and therefore a species concept of such mycorrhizae could not be provided. The same applies to identified mycorrhizae; partially because of poor descriptions and partially because identifications of mycorrhizae - by finding connections between mycorrhizae and fruitbodies - have been to few up to now. The same holds true for the present investigation. Such studies of the variability - inclusive of variability depending on age - are urgently needed, but this must be the task of time consuming monographical studies. At present it is a step forward to have single specimens of mycorrhizae described precisely.

A further advance may be obtained by studying the variability of ectomycorrhizae when synthesized in different soils, under different environmental circumstances and with a variety of hosts. ALEXANDER (1981) attempted this approach using the mycorrhizae of _Lactarius rufus_ + _Picea sitchensis._ The synthesized mycorrhizae did not show differences in response to different conditions of syntheses. Such studies as well as researches on the variation of mycorrhizae isolated from soil would greatly assure in the characterization and classification of ectomycorrhizae.

IV ACKNOWLEDGEMENTS

I am very much obliged to Mr. P. Altheide for having skillfully prepared and stained sections and to Mr. K. Liedl who has made the prints of the photos and drawings. In addition I am thanking all members of my staff for kind co-operation and discussing a lot of problems. Last not least I am very thankful to Dr. David J. Read (Sheffield) and Dr. Jim M. Trappe (Corvallis) for critical comments on the manuscript and for improving the English text.
This study was supported by "DFG, Deutsche Forschungs Gemeinschaft, grant Ag 7/5-2". Dachser Spedition (Munich), Daimler-Benz AG (Stuttgart) and Carl Zeiss AG (Oberkochen) susidized the investigations by a "fund for researching the tree die-back".

V LITERATURE

AGERER, R. (1985) - Zur Ökologie der Mykorrhizapilze. Bibl. Myc. 97: 1 - 160.
-- (1986) - Studies on ectomycorrhizae II. - Introducing remarks on characterization and identification. Mycotaxon 26: - .
ALEXANDER, I. J. (1981) - The Picea sitchensis + Lactarius rufus mycorrhizal association and its effects on seedling growth and development. Tr. Br. Myc. Soc. 76 (3): 417 - 423.
ACSAI, J. & D. L. LARGENT (1983) - Ectomycorrhizae of selected conifers growing in sites which support dense growth of bracken fern. Mycotaxon 16(2): 509 - 518.
BRUCHMANN. H, (1874) - Über Anlage und Wachstum der Wurzeln von Lycopodium und Isoetes. Jen. Z. Med. Nat. 8: 522 - 578.
CERUTI, A. & L. BUSSETTI (1962) - Sulla simbiosi micorriza tra tigli e Boletus subtomentosus, Russula grisea, Balsamia platyspora, Hysterangium clathroides. Allionia 8: 55 - 66.
CHILVERS, G. A. (1968) - Some distinctive types of Eucalypt mycorrhiza. Aust. J. Bot. 16: 49 - 70.
CHU-CHOU, M. (1979) - Mycorrhizal fungi of Pinus radiata in New Zealand. Soil Biol. Biochem. 11: 557 - 562.
CLEMENCON, H. (1978) - Siderophilous granules in the basidia of Hymenomycetes. Persoonia 10(1): 83 - 96.
DOMINIK, T. (1969) - Key to ectotrophic mycorrhizae. Folia For. Polonica Ser A 15: 309 - 328.
DUDDRIDGE, J. A., A. MALIBARI & D. J. READ (1980) - Structure and function of mycorrhizal rhizomorphs with special reference to their role in water transport. Nature (Lond.) 287: 834 - 836.
-- & D. J. READ (1984) - Modification of the host-fungus interface in mycorrhizas synthesized between Suillus bovinus and Pinus silvestris. New Phytol. 96(4): 583 - 588.
FLEMING, L. V., J. W. DEACON, F. T. LAST & S. J. DONALDSON (1984) - Influence of propagating soil on the mycorrhizal succession of birch (Betula pendula) seedlings transplanted to a field site. Tr. Br. Myc. Soc. 82(4): 707 - 712.

FOSTER, R. C. (1981) - Mycelial strands of Pinus radiata D. Don: ultrastructure and histochemistry. New Phytol. 88: 705 - 712.

FRANK, A. B (1885) - Über die auf Wurzelsymbiose beruhende Ernährung gewisser Bäume durch unterirdische Pilze. Ber. Dtsch. Bot. Ges. 3: 128 - 145.

FROIDEVAUX, L. (1973) - The ectomycorrhizal association, Alnus rubra + Lactarius obscuratus. Can. J. For. Res. 3: 601 - 603.

GIBELLI, G. (1883) - Nuovi studii sulla malattia del castagno detta dell'inchiostro Mem. Reale Accad. Sci. Inst. Bologna 4: 287 - 314.

GRÖGER, F. (1968) - Zur Kenntnis von Lactarius semisanguifluus Heim et Leclair. Westfäl. Pilzbr. 7(3): 3 - 12.

GODBOUT, G. & J. A. FORTIN (1985) - Classification of ectomycorrhizae: what's new and what to do. Proc. NACOM VI: 186 - 188.

-- & -- (1985a) - Synthesized ectomycorrhizae of aspen: fungal genus level of structural characterization. Can. J. Bot. 63: 252 - 262.

HARLEY, J. L. & S. E. SMITH (1983) - Mycorrhizal symbiosis. Acc. Press, London.

HATCH, A. B. & K. D. DOAK (1933) - Mycorrhizal and other features of the root systems of Pinus. J. Arnold Arb. 14: 85 - 99.

-- & C. HATCH (1933) - Some Hymenomycetes forming mycorrhizae with Pinus strobus L. J. Arnold Arbor. 14: 324 - 344.

LAIHO, O. (1970) - Paxillus involutus as a mycorrhizal symbiont of forest trees. Acta For. Fenn. 106: 1 - 72.

LUPPI, A. M. & C. GAUTERO (1967) - Ricerche sulle micorrize di Quercus robur, Q. petraea and Q. pubescens in Piemonte. Allionia 13: 129 - 148.

MANGIN, L. (1910) - Introduction a l'etude des mycorhizes des arbres forestiers. Nouv. Arch. Mus. d'Hist. Nat. 5. Ser. 2: 245 - 276.

MASUI, K. (1926) - A study of the mycorrhiza of Abies firma with special reference to its mycorrhizal fungus, Cantharellus floccosus. Mem. Coll. Sci. Kyoto Imp. Univ. Ser. B 2(1): 15 - 84.

-- (1926a) - A study of the ectotrophic mycorrhiza of Alnus. Mem. Coll. Sci. Kyoto Imp. Univ. Ser. B 2(4): 190 - 209.

-- (1926b) - The compound mycorrhiza of Quercus pausidentata Fr. Mem. Coll. Sci. Kyoto Imp. Univ. Ser. B 2(4): 161 - 187.
-- (1927) - A study of ectotrophic mycorrhizas of woody plants. Mem. Coll. Sci. Kyoto Imp. Univ. B III (2): 149 - 279.
-- (1923) - Experimentelle Untersuchungen über die Konstitution und Ökologie der Mykorrhizen von Pinus silvestris L. und Picea abies (L.) Karst. In: Falck, R. (ed.) Mykologische Untersuchungen und Berichte 2: 73 - 331.
-- (1924) - Zur Kenntnis der Mykorrhizapilze von Pinus montana Mill. Bot. Notiser 1924: 69 - 92.
-- (1924a) - Über den Einfluß der Wasserstoffionenkonzentration auf die Virulenz der Wurzelpilze von Kiefer und Fichte. Bot. Notiser 1924: 38 - 48.
-- (1959) - Mycorrhiza. Handb. Pflanz.phys. 11: 605 - 631.
MEYER, F. H. (1985) - Einfluß des Stickstoff-Faktors auf den Mykorrhizabesatz von Fichtensämlingen im Humus einer Waldschadensfläche. Allg. Forstzeitg. 9/10: 208 - 219.
MISHRA, R. R. & G. D. SHARMA (1981) - Studies on mycorrhizal association of Pinus kesiya (Royle). J. Ind. Bot. Soc. 60(2): 168 - 171.
MODESS, O. (1941) - Zur Kenntnis der Mykorrhizabildner von Kiefer und Fichte. Symb. Bot. Ups. 5(1): 1 - 146.
MOSER, M. (1978) - Die Röhrlinge und Blätterpilze. In Gams, H. Kleine Kryptogamenflora IIb/2. Fischer, Stuttgart, New York.
MOSSE, B., D. P. STRIBLEY & F. LE TACON (1981) - Ecology of mycorrhizae and mycorrhizal fungi. Adv. Microbiol. Ecol. 5: 137 - 210.
OGAWA, M. (1981) - Ecological characters of ectomycorrhizal fungi and their mycorrhizae. IUFRU World Congr. XVII: 89 - 95.
PACHLEWSKI, R. (1968) - /Untersuchungen über Mykorrhiza-Pilze der Fichte. - Lactarius rufus (Scop.) Fr. und Rhizopogon luteolus Fr. et Nordh. - unter natürlichen Bedingungen und in Reinkulturen./ Prace Inst. Bad. Les. 365: 173 - 187.
PALM, M. E. & E. L. Stewart (1984) - In vitro synthesis of mycorrhizae between presumed specific

and nonspecific Pinus and Suillus combinations. Mycologia 76: 579 - 600.

PICHE, Y., R. L. PETERSON & C. A. ACKERLEY (1983) - Early development of ectomycorrhizal short roots of pine (Pinus strobus). Scann. Elect. Mic. 1983(3): 1467 - 1474.

RIFFLE, J. W. (1973) - Pure culture syntheses of ectomycorrhizae on Pinus ponderosa with species of Amanita, Suillus and Laccaria. Forest Sci. 19: 242 - 250.

ROMAGNESI, H. (1958) - Recherches sur les Lactaires a lait rouge (Dapetes Fr.). Rev. Myc. 23: 261 - 281.

-- (1967) - Les Russules d'Europe et d'Afrique du Nord. Bordas.

SCHAEFFER, J.(1952) - Russula Monographie. Bad Heilbrunn.

SCHMITT, J. A. (1974) - Chemotaxonomische, morphologische und pflanzensoziologische Studien an mitteleuropäischen Lactarius-Arten der Sektion Dapetes Fr. (Blutreizker). Z. Pilzkde. 39: 219 - 244.

SEVIOUR, R. J., D. HAMILTON & G. A. CHILVERS (1978) - Scanning electron microscopy of surface features of Eucalypt mycorrhizas. New Phytol. 80: 153 - 156.

SLANKIS, V. (1948) - Einfluß von Exsudaten von Boletus variegatus auf die dichotomische Verzweigung isolierter Kiefernwurzeln. Phys. Plant. 1: 390 - 400.

STRULLU, D. G. (1973) - Aspects d'une mycorrhize ectotrophe de Douglas en microscopie electronique a balayage. Rev. For. Fr. (Nancy) 25: 534 - 537.

-- (1979) - Ultrastructure et representation spatiale du manteau fongique des ectomycorrhizes. Can. J. Bot. 57: 2319 - 2324.

THOMAS, G. W. & R. M. JACKSON (1979) - Sheathing mycorrhizae of nursery grown Picea sitchensis. Tr. Myc. Soc. 73: 117 - 125.

-- & -- (1982) - Scanning electron microscopy of sheathing mycorrhizas of Sitka spruce (Picea sitchensis). Tr. Br. Myc. Soc. 79(1): 31 - 40.

TRAPPE, J. M. (1967) - Pure culture syntheses of Douglas fir mycorrhizae with species of Hebeloma, Suillus, Rhizopogon and Astraeus. Forest Sci. 13: 121 - 130.

VOIRY, H. (1981) - Classification morphologique des ectomycorhizes du Chêne et du Hetre dans le nord-est de la France. Eur. J. For. Pathol. 11: 284 - 299.

ZAK, B. (1969) - Characterization and classification of mycorrhizae of Douglas fir I. Pseudotsuga menziesii + Poria terrestris (blue- and orange-staining strains). Can. J. Bot. 47: 1833 - 1840.

-- (1971) - Characterization and classification of mycorrhizae of Douglas fir II. Pseudotsuga menziesii + Rhizopogon vinicolor. Can. J. Bot. 49: 1079 - 1084.

-- (1971a) - Characterization and identification of Douglas fir mycorrhizae. Proc. NACOM 1st. pp. 38 - 53.

-- (1973) - Classification of ectomycorrhizae. In Marks, G. C. & T. T. Kozlowski (eds.): Ectomycorrhizae, their ecology and physiology. Ac. Press New York, London.

-- & M. J. LARSEN (1978) - Characterization and classification of mycorrhizae of Douglas-fir III. Pseudotsuga menziesii + Byssoporia (Poria) terrestris vars. lilacinorosea, parksii, and sublutea. Can. J. Bot. 56(12): 1416 - 1424.

MYCOTAXON

Vol. XXVII, pp. 61-62 October-December 1986

A NEW SPECIES OF THE GENUS OIDIUM FROM INDIA

G. Bagyanarayana

Osmania University, Department of Botany,
Hyderabad (A.P.), India

U. Braun

Pädagogische Hochschule "Wolfgang Ratke"
Sektion Biologie/Chemie, WB. Botanik II
DDR-4370 Köthen, Lohmannstr. 23, G.D.R.

Oidium pavoniae G. Bagyanarayana & U. Braun spec. nov.

Mycelio amphigeno, albo. Hyphis sterilibus rependibus, hyalinis, ramosis, flexuosis, septatis, appressoriis non lobatis vel lobatis. Conidiophoris simplicibus, ex hyphis sterilibus oriundis, cellulis ad basim cylindraceis, rectis, 45-80 x 6.5-10 µm, conidiis solitariis, ellipsoideis -cylindraceis vel cylindraceis - doliiformibus, (30-) 35-50 x 14-21.5 µm.

Holotypus: India, Hyderabad, A.P., 16-12-1984, G. Bagyanarayana; type host - *Pavonia zeylanica* Cav. (HAL).

Mycelium amphigenous, white, patches or effused, hyphae hyaline, septate, branched, ca 2.5-8 µm wide, appressoria nipple-shaped to slightly lobed, conidiophores erect, foot-cells straight, cylindric, long, 45-80 x 6.5-10 µm, followed by 1-3 shorter cells, the second cell sometimes as long as the foot-cell, conidia formed singly, ellipsoid - cylindric or cylindric - doliform, (30-) 35-50 x 14-21.5 µm. Fig. 1.

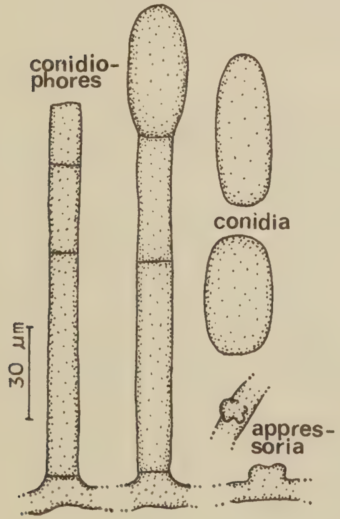


Fig. 1. *O. pavoniae* spec. nov.

The known *Oidium* species on host plants of the Malvaceae are distinguished from *O. pavoniae* by the following features: *Oidium abelmoschi* Thüm. (conidia in chains, smaller), *O. schmiedeknechtii* U. Braun (foot-cells of the conidiophores short, ca 30-40 µm long), *O. urenae* Yen (foot-cells of the conidiophores very long, ca 60-200 µm, conidia ovoid-doliform).

MYCOTAXON

Vol. XXVII, pp. 63-69 October-December 1986

CONIOCHAETIDIUM MIRABILE, A NEW ASCOMYCETE ISOLATED FROM SALTED FOOD

Shun-ichi UDAGAWA[1] and Haruo TSUBOUCHI[2]

[1] *National Institute of Hygienic Sciences, Kamiyoga 1-chome, Setagaya-ku, Tokyo 158, Japan*
[2] *Nagoya City Health Research Institute, Hagiyama-cho, Mizuho-ku, Nagoya 467, Japan*

SUMMARY

A new species of *Coniochaetidium* isolated from salted food (dried powder of salmon and 'wakame' (*Undaria pinnatifida*)) is described. The species, *C. mirabile*, differs from *C. ostreum*, the type species of *Coniochaetidium*, in the morphological characteristics in culture.

During a microbiological study of retailed salted foods in Nagoya City of central Japan, the junior author found a small colony of a cleistothecial ascomycete on a diluted plate of dried powder of salmon and 'wakame' (*Undaria pinnatifida* (Harvey) Suringar) for cooking of a rice ball. The fungus occurred on the plate of potato-dextrose agar (PDA) with 20% sucrose at 25°C and was isolated on the PDA slant medium. After observation on the media suitable for its growth, we determined that this fungus is a typical member of *Coniochaetidium* in the Coniochaetaceae (Ascomycetes). It is described as a new species of the genus.

Coniochaetidium mirabile Udagawa & Tsubouchi, sp.nov.
(Figs. 1-6)
Stat. Anam. *Cladobotryum*.

Coloniae in agaro farina avenacea restrictae, plus minusve floccosae, irregulariter sulcatae, tenues, primo albae, deinde roseo-vinosae vel dilute rubrae; ad centrum ascomata abundanter producta, cinerascentia; reversum roseo-bubalinum vel testaceum.

Ascomata superficialia, in catervis parvis aggregata, cinerea, globosa vel subglobosa, 185-280 µm diam, saepe ex hyphis hyalinis, confertis obtecta, nonostiolata. Peridium ascomatis tenue, ca. 8-10 µm crassum, atrobrunneum, bistratum; stratum exterius ex interjectis 'textura intricata' -'textura angularis' et cellulis incrassatis, brunneis, 3-7 µm diam compositum; stratum inferius ex 'textura globulosa' et cellulis tenuibus, hyalinis, globulosis, 6-20 µm diam compositum. Asci singulares et irregulariter dispositi, 2-8-spori, subglobosi vel ovoidei vel pyriformes, 12-15 × (8-)10-11 µm, tenues, evanescentes. Ascosporae valde olivaceo-brunneae vel atrobrunneae, unicellulares, lenticulares, 5-6(-10) × 4.5-5(-8) × 3.5 µm, superficies convexae laeves, fissura germinali aequatoriali notata et duabus cristis aequatorialibus ca. 0.5 µm latis praeditae.

Mycelium ex hyphis hyalinis, ramosis, septatis, laevibus, 2-4.5 µm latis compositum. Conidiophora micronemata vel semimacronemata, mononemata, suberecta, hyalina, simplicia vel aliquanto subverticillate ramosa, 10-25 × 1.5-3.5 µm, laevia, septata. Cellulae conidiogenae discretae, singulares vel 2-3(-4) in verticillo disposae, rectae vel parum curvatae, subulatae, saepe ad medium inflatae et sursum angustatae, hyalinae, laeves, vulgo 10-28 × 2.5-3 µm. Conidia holoblastica, apice cellularum conidiogeneorum oriunda, uni-cellularia, hyalina, laevia, tenuia, late ellipsoidea vel pyriformia vel clavata, 3-7(-10) × 2.5-5 (-6.5) µm, superne rotundata et basi anguste truncata, saepe cicatrice basali instructa, in catenis brevibus fragilibus cohaerentia.

Holotypus: cultura NHL 2960, ex cibo sicca, Nagoya in Japonia, in 1984.9 a H. Tsubouchi, isolata. In collectione fungorum 'National Institute of Hygienic Sciences (NHL), Tokyo, Japan'.

Etymology: Lat. *mirabilis*=extraordinary, referring to the unusual habitat of this fungus.

Colonies on oatmeal agar growing restrictedly, attaining a diameter of 2.7-2.8 cm within 28 days at 23°C, more or less floccose, irregularly furrowed, composed of a thin basal felt with scattered patches of dense aerial mycelium, at first white, then quickly changing to pink color near Rosy Vinaceous (Rayner, 1970) or pale red (Methuen 8A3 in Kornerup and Wanscher, 1978); ascomata abundantly produced at colony center, usually obscured by the overlying aerial growth, grayish in color; reverse Rosy Buff to Brick (Rayner) or brownish orange (Methuen 7C4).

Ascomata superficial on the mycelial felt, gregarious in small clusters, gray, globose to subglobose, 185-280 µm

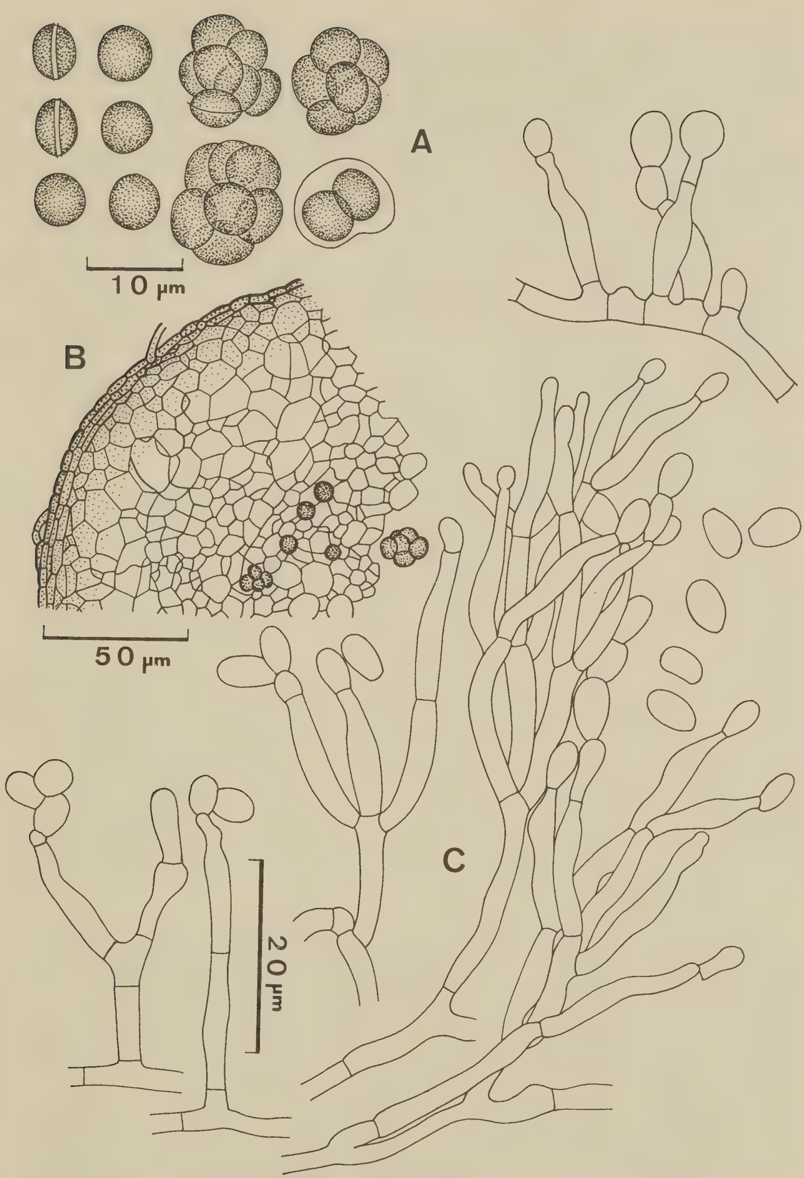

A
10 μm
B
50 μm
C
20 μm

Figure 1. *Coniochaetidium mirabile*. A. Asci and ascospores. B. A portion in cross section of ascoma. C. Conidiophores, conidiogenous cells and conidia.

in diam, often covered with hyaline, dense hyphal wefts, nonostiolate. Ascomatal peridium thin, ca.8-10 µm thick, dark brown, two-layered, with a pigmented outer layer composed of an intermediate between *textura intricata* and *textura angularis* with thick-walled, brown cells 3-7 µm in diam, and inner layer thin, hyaline, of *textura globulosa* with globular cells 6-20 µm in diam. Asci singly borne on ascogenous hyphae, irregularly disposed, 2-8-spored, subglobose to ovoid or pyriform, 12-15 × (8-)10-11 µm, nondextrinoid, thin, without apical structures, evanescent. Ascospores dark olive-brown to dark brown, one-celled, irregular in shape and size, lenticular, subglobose to oblate in face view, 5-6(-10) × 4.5-5(-8) × 3.5 µm, smooth-walled, with an equatorial germ slit dividing the spore into two equal valves, provided with two hyaline equatorial ridges measuring ca.0.5 µm in width, germinating by the production of one to two germ tubes.

Mycelium composed of hyaline, branched, septate, smooth-walled, 2-4.5 µm diam hyphae. Conidiophores micronematous to semimacronematous, mononematous, suberect, hyaline, unbranched or branched in somewhat verticillate-arrangements, 10-25 × 1.5-3.5 µm, smooth-walled, septate. Conidiogenous cells discrete, borne singly or in groups of 2-3(-4), straight or slightly curved, subulate, often swollen at middle and narrower at the blunt apex, hyaline, smooth-walled, mostly 10-28 × 2.5-3 µm. Conidia holoblastic, produced retrogressively as a terminal blow-out at the tip of individual conidiogenous cells, one-celled, hyaline, smooth and thin-walled, broadly ellipsoidal to pyriform or clavate, 3-7(-10) × 2.5-5(-6.5) µm, rounded above and narrowly truncate at the base, often with a prominent basal scar, produced in short fragile chains up to 50 µm in length.

Growth at 37°C is nil.

Water relations (at 25°C, 14 days): on MY50G, water activity of 0.89 (Pitt and Hocking, 1985), colonies 5.3 mm in diam; on MY5-12, water activity of 0.93 (Pitt and Hocking), colonies 23.1 mm in diam; on MY10-12, water activity of 0.88 (Pitt and Hocking), colonies 13.8 mm in diam. Further observation shows in Table 1.

Specimen examined: ex dried salted food (powder of salmon and 'wakame' (*Undaria pinnatifida* (Harvey) Suringar); the salt contents 38-40%), Nagoya-City, Aichi-Pref., Japan, September 1984, coll. H. Tsubouchi, NHL 2960 (Holotype).

Coniochaetidium mirabile can be distinguished from *C. ostreum* Malloch & Cain (Malloch and Cain, 1971), the type species of the genus, by the irregular production of 2 to 8

ERRATA, VOLUME TWENTY-SEVEN

Page 67 line 17 *for* (%, v/v) *read* (%, w/v)

ascospores per ascus and the anamorph, which is more complexly branched. The ascospores of *C. mirabile* and *C. ostreum* (5.0-8.0 × 4.0-5.5 µm fide Malloch and Cain, 1971) have a similar range in size, but those of the former have hyaline equatorial ridges. In this respect of the spore ornamentation, *C. mirabile* is very close to two unpublished collections of *Coniochaetidium* from dead wood, in the Cryptogamic Herbarium of the University of Toronto: TRTC 33447 and TRTC 45662, both have hyaline equatorial flanges on the ascospores. However, both the collections are separated from *C. mirabile* by their larger ascospore dimensions, clavate and long-stipitate asci, and of a *Graphium*-like synnematous anamorph.

Table 1. The effect of a_w on growth of *Coniochaetidium mirabile* in PDA medium containing sodium chloride

NaCl	a_w	Colony diam (mm) after incubation at 25°C in				
(%, v/v)		1 wk	2 wk	3 wk	4 wk	5 wk
0	0.996	4.2	11.4*	17.0	21.4	25.3
5	0.972	10.0*	23.0	29.1	31.8	32.3
10	0.938	8.8*	19.5	28.1	32.9	36.2
15	0.906	1.5	9.0*	14.9	20.5	25.6
20	0.875	<1.0	<1.0	5.5*,**	9.9**	12.6**

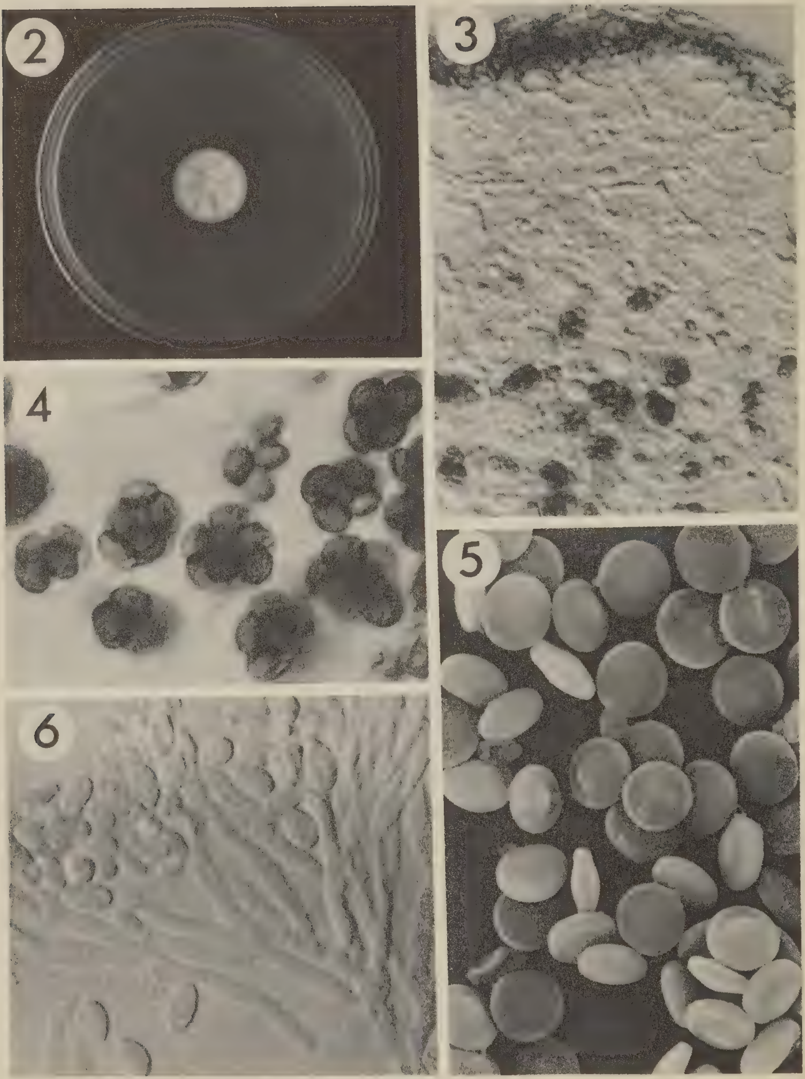
* First observed time (week) for conidial formation.
** Growth was observed on half of total 12 plates tested.

The *Cladobotryum* anamorph of *C. mirabile* is characterized by diffusely verticillate conidiophores and fragile chains of hyaline, one-celled conidia which are produced holoblastically from a determinate, retrogressive conidiogenous cell.

As might be expected from its spoilage of high salt content food, the fungus grew best on PDA containing 5% and 10% v/v NaCl (see Table 1). However, its salt-tolerance is not as high for sexual reproduction, showing no sign of any teleomorph at a_w levels below 0.972, despite rather profuse asexual sporulation within the experimental period.

ACKNOWLEDGMENTS

Appreciation is expressed to Professor D. Malloch of the University of Toronto for his useful suggestion and reviewing the manuscript. The authors are also indebted to Dr. Y. Otani for correcting the Latin diagnosis.



Figures 2-6. *Coniochaetidium mirabile*. 2. Colony on PDA + 5% NaCl after 14 days at 25°C. ×1/2. 3. A portion in cross section of ascoma. ×450. 4. Asci. ×1050. 5. S.E.M. of ascospores. ×1900. 6. Conidiophores, conidiogenous cells and conidia. ×880.

LITERATURE CITED

Kornerup, A., and J.H. Wanscher. 1978. Methuen Handbook of Colour. 3rd ed. Eyre Methuen, London.

Malloch, D., and R.F. Cain. 1971. New cleistothecial Sordariaceae and a new family, Coniochaetaceae. Can. J. Bot. 49: 869-880.

Pitt, J.I., and A.D. Hocking. 1985. New species of fungi from Indonesian dried fish. Mycotaxon 22: 197-208.

Rayner, R.W. 1970. A Mycological Colour Chart. Commonwealth Mycological Institute, Kew & the British Mycological Society.

MYCOTAXON

Vol. XXVII, pp. 71-82 October-December 1986

MATERIALS FOR A LICHEN FLORA OF THE ANDAMAN ISLANDS-I

M.B. NAGARKAR, P.K. SETHY & P.G. PATWARDHAN

Department of Mycology, M.A.C.S. Research Institute, Pune-411 004, India.

ABSTRACT

Eighteen species of Thelotremataceae from the Andaman Islands, India are described. *Leptotrema pertusarioides*, *Ocellularia wandoorensis* and *Thelotrema guptei* are new species. *L. nuwarense*, *O. olivacea*, *O. xanthostromiza* and *T. recurvum* are additions to the lichen flora of India.

INTRODUCTION

Oceanic islands have always attracted the attention of floristic botanists. In his famous lecture on "Insular Floras", delivered at Nottingham on 27th August 1866, Joseph Dalton Hooker remarked, "The relationships between these oceanic island Floras are of two kinds.....One a relationship of analogy between themselves, due to physical conditions common to them all- to their climate, exposure, limited area, distance from continents etc. Thus they are rich in Ferns, Mosses and other Flowerless plants.....Species are few in proportion to genera, and genera in proportion to the orders.....The other is a relationship of affinity, a *bona fide* kinship, which the Floras of islands display in common with one another or with certain continents." (Williamson, M. 1984).

The Andaman islands attracted the attention of floristic botanists as early as 1791 (Thothathri 1960) but lichens were first collected from these islands in 1867 by Dr.Kurz of the Royal Botanic Garden, Calcutta.

Reports of 62 taxa identified by Nylander (1873), 24 taxa by Jatta (1905) and 47 species of foliicolous lichens by Ajay Singh (1979) form the major contribution to our knowledge of the lichens of the Andaman islands. Ajay Singh (1979) has listed all the taxa reported so far and reviewed earlier work on lichens from these islands.

In 1985 we made lichen collections on the Andaman islands under a project entitled,"Lichen flora of the Andaman islands" sponsored by the Department of Science and Technology, New Delhi, India. We propose to describe and revise the lichen taxa from these islands in a series of papers, as we complete studies of the various families.

The Andamans constitute a group of islands lying in the Bay of Bengal between 13° 41' and 10° 30' N latitude and 92° 11' and 93° 7' E longitude, 1100 km from the Coromandel coast of the Indian mainland and 515 km from the Tenasserim coast of Burma. The land area of the entire group of 204 islands is about 6330 km^2. The main group consists of North Andaman, Middle Andaman and South Andaman. Little Andaman is located south of the main group (Great) of the Andamans.

The vegetation of the islands is classified under six types (Thothathri 1962):

1. Mangrove forest (confined to creeks)
2. Beach forest (on the coast and extending somewhat inland)
3. Deciduous forest
4. Evergreen forest at lower elevations
5. Moist evergreen forest at higher elevations
6. Vegetation in cleared areas

In his studies on the flora of the Andaman islands Thothathri (1960) concluded, "In general it may be summed up that the flora of the Andaman Islands is an admixture of Burmese and Malayan plants together with its indigenous plants."(p. 361).

In this paper we deal with 18 species of the four ascospore-based genera *Leptotrema, Ocellularia, Phaeotrema* and *Thelotrema* in the lichen family Thelotremataceae. Several others remain to be studied. Distribution records outside of the islands are taken from Hale (1974, 1978, 1981), from our own identified materials in AMH and from examination of types.

Leptotrema elachistoteron (Leighton) Patw.& Kulk., *Norw. J. Bot.*, **24:** 128 (1977). (Fig. 1)
Thelotrema elachistoteron Leighton, *Trans. Linn. Soc. London*, **27**: 169(1869).

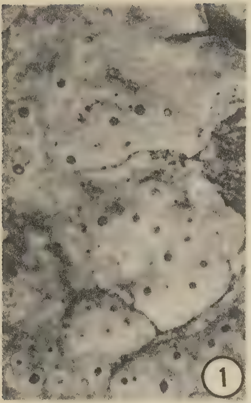
Thallus pale yellowish gray to straw coloured, smooth, uneven, medulla 50-100 µm thick, epiphloeodal; apothecia many, solitary, immersed to slightly raised, 0.2-0.4 mm diam; ostiole minute, round, slightly raised dark brown rim. 80-130 µm across; exciple fused, colourless to reddish brown at the apex only; hymenium 100-150 µm high, 200-250 µm broad; ascospores brown, muriform, 2-4 per ascus, 15-20 X (42) 60-85 µm, I + violet.

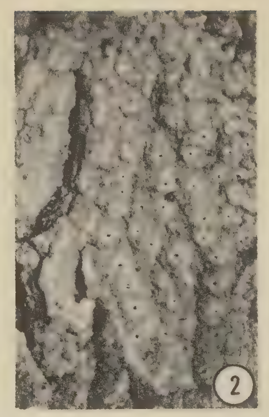
Chemistry: Thallus K + deep yellow, P + orange; stictic and constictic acids present.

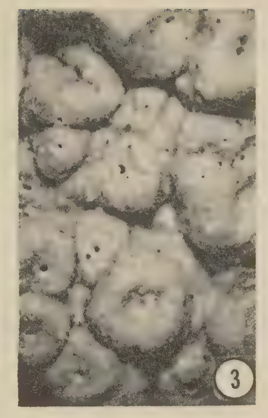
Specimens examined: South Andaman, Baratang island, Lorojig - 85.237, 262, 264, 227.

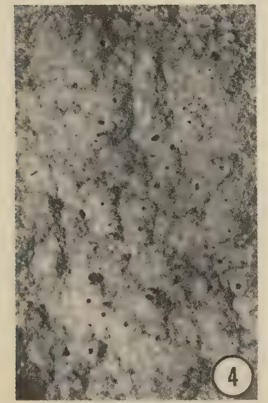
Distribution: Sri Lanka, India.

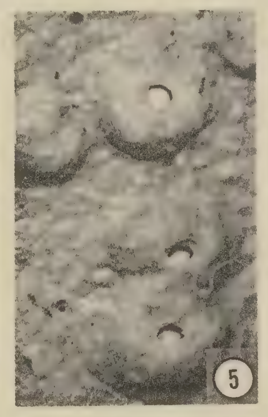
Leptotrema reclusum (Krempelh.) Zahlbr., a comparable species, has larger ascospores exceeding 100 µm in length.

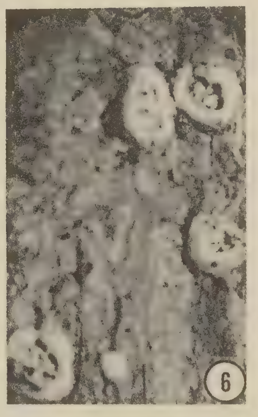

①

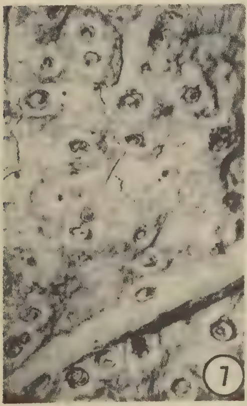

②

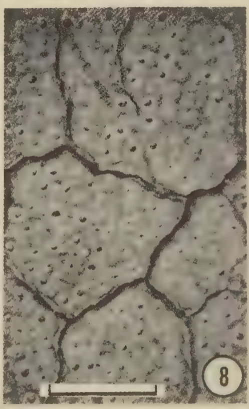

③

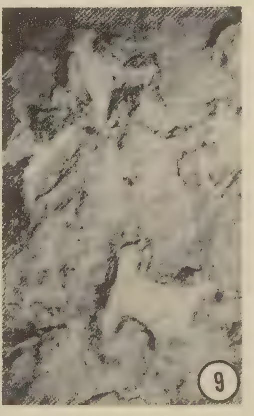

④


⑤


⑥


⑦


⑧


⑨

Leptotrema nuwarense (Hale) *comb. nov.* (Fig. 2)
Myriotrema nuwarense Hale, *Bull. Br. Mus. nat. Hist.* (*Bot.*) **8** (3): 289 (1981).

Thallus pale greenish gray, uneven, cracked, medulla 100-130 µm thick, crystalloid, partly hypophloeodal; apothecia numerous, solitary, immersed, 0.2-0.35 mm diam; ostiole minute, round, off-white annulate rim, 180-250 µm across; exciple free, inner exciple forming a ring, colourless; hymenium 100-130 µm high, 200-250 µm broad; ascospores brown, muriform, 2 per ascus, 10-15 X 42-55 µm, I-.

Chemistry: Thallus K + yellow, P + orange; stictic and constictic acids present.

Specimens examined: South Andaman, Wandoor, Alexandria island - 85.1108b, 1035, 1104, 1106.

Distribution: Sri Lanka, India.

Leptotrema pertusarioides, sp. nov. (Fig. 3)

Thallus corticola, pallide fulvo-cinereus, verrucosus, crassus, pro parte hypophloeodes; apothecia numerosa, congesta, emergentia, basin constricta, 0.6 - 0.85 mm diametro; ostiolum rotundatum, apertum, depressum, 200-400 µm diametro; excipulum connatum, non-carbonaceum; columella nulla; hymenium 200-250 µm altum; sporae octonae, fuscae, late ellipsoideae, 4-loculatae, 10-12 X 15-18 µm.

Thallus pale yellowish gray, warty, medulla 160-250 µm thick, crystalloid, partly hypophloeodal; apothecia numerous, crowded, emergent, constricted at the base, 0.6-0.85 mm diam; ostiole open, depressed, 200-400 µm across; exciple fused, reddish yellow; hymenium 200-250 µm high, 250-320 µm broad; ascospores brown, muriform, 8 per ascus, broadly ellipsoidal with 1 transverse septum in the middle and 1 faint vertical septum forming 2 locules in each half, 10-12 X 15-18 µm.

Chemistry: Thallus K + yellow, P + blood red; protocetraric acid present.

Typus: India, Andaman islands, South Andaman, Wandoor, Alexandria island, leg. M.B. NAGARKAR and P.K. SETHY, 6 March 1985, 85.1115 (AMH-*holotypus*; US-*isotypus*).

This species has apothecia extremely similar to those of the genus *Pertusaria*, but the spores are typically broadly ellipsoid with one distinct transverse septum and two locules in each compartment.

Leptotrema bahianum (Ach.) Müll. Arg., another species with protocetraric acid, has somewhat larger ascospores (12-14 X 16-24 µm) with 5-6 transverse and 2-3 longitudinal locules.

Leptotrema reclusum (Krempelh.) Zahlbr., *Cat. Lich. Univ.*, **2**: 639 (1924). (Fig. 4)
Thelotrema reclusum Krempelh. in *Nyl.*, *Bull. Soc. Linn. Normand.*, **7**(2): 168 (1873).

Thallus brownish gray, rough, becoming cracked in mature stage, medulla 150-200 µm thick, crystalloid, epiphloeodal; apothecia numerous, solitary, immersed to slightly raised, 0.3-0.5 mm diam; ostiole round, moderately open, 100-200 µm across; exciple fused, pale yellow; hymenium 180-220 µm high, 250-310 µm broad; ascospores brown, muriform, 1 per ascus, 18-32 X (73)96-126 µm, I-.

Chemistry: Thallus K + yellow, P + orange, stictic and constictic acids present.

Specimens examined: South Andaman, Wimberliganj, Kalatang- 85.1217, Wandoor, Alexandria island- 85.1111.

Distribution: Panama, India.

Ocellularia allosporoides (Nyl.) Patw.& Kulk., *Kavaka*, **5**: 5 (1977). (Fig. 5)
Thelotrema allosporoides Nyl., *Bull. Soc. Linn. Normand.*, **7**(2): 167 (1873).

Thallus greenish gray to yellowish gray, smooth to rough, medulla 160-200 µm thick, corticated, epiphloeodal; apothecia numerous, solitary, semi-emergent to emergent, 1.2-1.8 mm diam; ostiole depressed, open, 360-630 µm across; exciple carbonized laterally; columella simple, tip white pruinose, carbonized, 400-600 µm thick; hymenium 200-250 µm high; ascospores hyaline, transversely septate, 4 per ascus, 12-15 X 96-128 µm, I + deep violet.

Chemistry: Thallus K-, P-; lacking lichen substances.

Specimens examined: Andaman islands, South Andaman, Chidya Tapu- 85.52, 59, 61, 69, 74(b), 75. Wimberliganj, Kalatang- 85.82, 89, 98, 105, 110, 131, 152, 153, 154, 205, 1215, 1216; Alexandria island- 85.1088, 1093, 1127, 1142.

Distribution: India, New Zealand.

Ocellularia berkeleyana (Mont.) Zahlbr., *Engler-Prantl, Naturl. Pflanzenfamil., 1. Teil, Abt*: 137 (1905). (Fig. 6)
Stegobolous berkeleyanus Mont. in *Hook. London J. Bot.*, **4**: 4 (1845).

Thallus light greenish gray, smooth, medulla 20-40 µm thick, corticated, epiphloeodal; apothecia many, solitary, emergent, constricted at the base, 0.6-1 mm diam; disc wide open, white pruinose, 300-600 µm across; thalline exciple erect, proper exciple carbonized laterally; columella actinoid with 3 to 4 branches, prominent from the exterior, protruding out as a white pruinose tip, carbonized; hymenium 70-90 µm high; ascospores hyaline, transversely septate, 8 per ascus, 3-5 X 12-15 µm, 4 loculate, I + violet.

Chemistry: Thallus K -, P + Yellow; psoromic acid present.

Specimen examined: South Andaman, Wandoor, Alexandria island- 85.1065.

Distribution: Guadeloupe, Panama, Cuba, Apiahy, Brazil, India, Java, Philippines, South Africa.

Ocellularia diacida Hale, *Mycotaxon*, **7**(2): 378 (1978). (Fig. 7)

Thallus olivaceous green to greenish gray, smooth, medulla 20-35 µm thick, corticated, hypophloeodal; apothecia numerous, solitary, semi-emergent, 0.5-0.75 mm diam; ostiole open, often filled with tip of the columella, brown to dark coloured rim, 147-210 µm across; exciple carbonized in the ostiolar region only, sometimes extend further; columella simple, distinct, formed of thick walled hyphae apically, 120-190 µm thick, carbonized; hymenium 80-110 µm high; ascospores hyaline, transversely septate, 8 per ascus, 4-7 X 16-32 µm, (3)5 - 8(10) loculate, I + violet.

Chemistry: Thallus K + pale yellow, P + pale yellow; 3-4 spots above norstictic level in TLC, 'diacida' unknown.

Specimens examined: South Andaman, Port Mount - 85.33, Wandoor, Alexandria island - 85.1056, 1059, 1074, 1075, 1094, 1097, 1108,1136.

Distribution: India, Sri Lanka.

Ocellularia olivacea (Fée) Müll. Arg. in *Mém. Soc. Phys. Hist. nat. Genève*, **29**(8): 7 (1887). (Fig. 8)
Myriotrema olivaceum Fée, *Essai Crypt.*: 103 (1824).

Thallus light greenish gray to ashy gray, smooth, deeply fissured, areolate, medulla 250-380 µm thick, epiphloeodal; apothecia numerous, solitary, immersed, 0.15-0.25 mm diam; ostiole round, slightly raised off-white annulate rim, 50-100 µm across; exciple free, thin, pale reddish, inner exciple forming a minute pore within the main pore; hymenium 70-90 µm high, 140-160 µm broad; ascospores hyaline, transversely septate, 8 per ascus, 5 X 12.5-15 µm, 4 loculate, I + violet.

Chemistry: Thallus K -, P -; 'olivacea' unknown present.

Specimen examined: South Andaman, Baratang island, Lorojig - 85.222.

Distribution: West Indies, Central and South America, Sri Lanka, New Caledonia, Marquesas islands.

The present species is comparable in ascocarp morphology and anatomy to *Ocellularia micropora* (Mont.) Müll. Arg. which contains psoromic acid and *Ocellularia glaucula* (Nyl.) Zahlbr. which contains hypoprotocetraric acid.

Ocellularia pycnophragmia (Nyl.) Zahlbr., *Cat. Lich. Univ.* **2**: 599 (1924). (Fig. 9)
Thelotrema pycnophragmium Nyl., *Sertum Lichen. Tropic Labuan et Singapore.* P. 5 (1891).

Thallus whitish gray, smooth, continuous, medulla 50-80 µm thick, crystals, mostly hypophloeodal; apothecia many, scattered, solitary, rounded to somewhat elongated, semiemergent, chroodiscoid, 0.6-1.2 mm diam; disc wide open, white pruinose; exciple free with periphysoids, thalline rim recurved, non-carbonized; hymenium 150-200 µm high, 500-800 µm broad; ascospores hyaline, transversely septate, 4-8 per ascus, 5 - 7.5 X 70 - 97.5 µm, 25-35 loculate, I + deep violet.

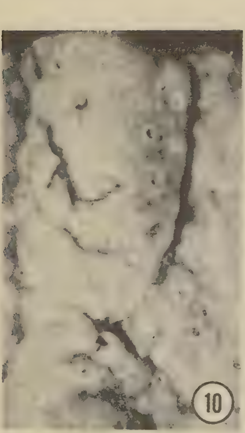
Chemistry: Thallus K-, P-; lacking lichen substances.

Specimens examined: South Andaman, Baratang island, Nilambur- 85.489, Wrafter's Crick- 85.568.

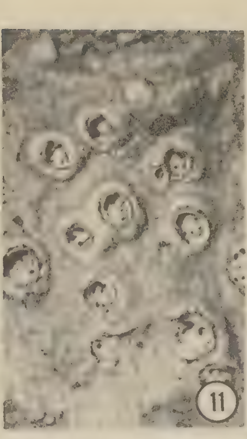
Distribution: Labuan, India.

Ocellularia terebrans (Nyl.) Zahlbr., *Cat. Lich. Univ.* **2**: 602 (1924). (Fig. 10)
Thelotrema terebrans Nyl., *Bull. Soc. Linn. Normand.*, **7**(2): 166 (1873).

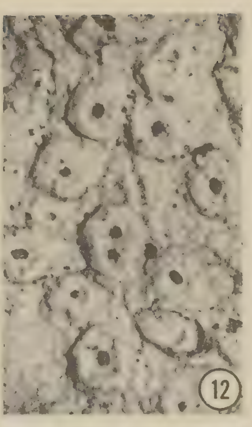
Thallus yellowish gray to straw coloured, shiny, warty, medulla 360-450 µm thick, studded with crystals, epiphloeodal; apothecia numerous, solitary, immersed, 0.25 - 0.35 mm diam; ostiole open, flush with the thallus, round, white rimmed, 150-200 µm across; exciple free, pale yellowish, inner exciple separated forming an inner ring, periphysoids; hymenium 120-150 µm high,



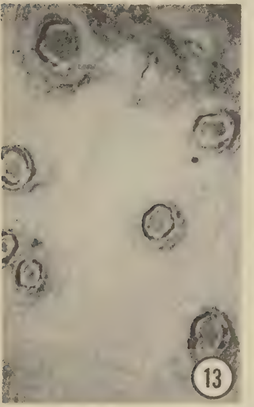
10



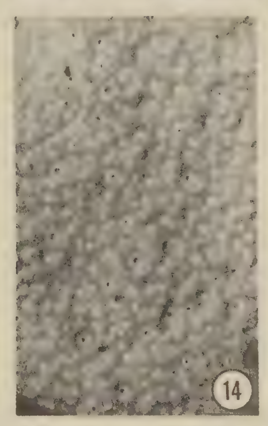
11



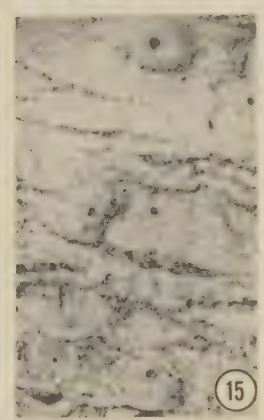
12



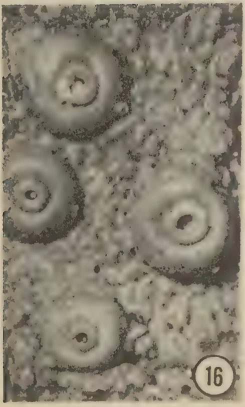
13



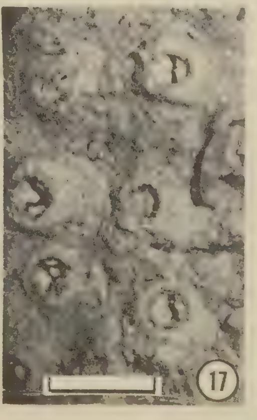
14



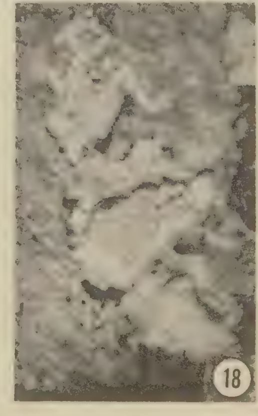
15



16



17



18

200-240 µm broad; ascospores hyaline, transversely septate, 8 per ascus, 4.8 X 19-25(30) µm, 7-10 loculate, I + pale blue.

Chemistry: Thallus K + deep yellow, P + orange; stictic acid present.

Specimen examined: South Andaman, Chidya Tapu- 85.63.

Distribution: India, Sri Lanka.

Ocellularia wandoorensis, *sp. nov.* (Fig. 11)

Thallus corticola, viridi-cinereus, verrucosus, hypophloeodes; apothecia numerosa, solitaria, arcte disposita semi-emergentia vel emergentia, 0.5-0.8 mm diametro; ostiolum rotundatum apertum, 0.2-0.3 mm diametro; excipulum connatum, intus carbonaceum; columella actinoidea, 3-4 furcata, badia vel fusca, apice epruinosa vel leviter albo-pruinosa; hymenium 50-70 µm altum; sporae octonae, incolores, transversim septatae, 4 loculatae, 3-5 X 8-10 µm, I + coeruleae.

Thallus greenish gray, warty, medulla 60-80 µm thick, corticated, hypophloeodal; apothecia numerous, solitary, closely disposed, semi-emergent to emergent, 0.5-0.8 mm diam; ostiole rounded, open, pore gaping, 230-300 µm across; exciple carbonized laterally; columella actionoid with 3 to 4 branches, reddish brown to dark brown, tip epruinose to lightly white pruinose; hymenium 50-70 µm high; ascospores hyaline, transversely septate, 8 per ascus, 3-5 X 8-10 µm, 4 loculate, I + violet.

Chemistry: Thallus K-, P-; lacking lichen substances.

Typus: India, Andaman Islands, South Andaman, Wandoor, Alexandria island, leg. P.K. Sethy and M.B. Nagarkar, 6 March 1985, 85.1103 (AMH-*holotypus*, US- *isotypus*).

Other specimens examined: South Andaman, Alexandria island, wandoor- 85.1080, 1102.

This species resembles to *Ocellularia berkeleyana* (Mont.) Zahlbr. in ascospore morphology. O. *berkeleyana* however, has a very prominent protruding columella with a heavily pruinose tip. The ostiolar region of the exciple and the disc are also pruinose, unlike O. *wandoorensis*. O. *glaziovii* Müll. Arg. has an even more highly developed actionoid disc.

Ocellularia xanthostromiza (Nyl.) Zahlbr., *Cat. Lich. Univ.* **2**: 604 (1924). (Fig. 12)

Ascidium xanthostromiza Nyl., *Sertum Lichen. Tropic. Labuan et Singapore:* 20 (1891).

Thallus greenish mineral gray, smooth to rugulose, cracked, medulla 150-180 µm thick, large crystals, partly hypophloeodal; apothecia numerous, crowded, emergent, constricted at the base (ascidioid), 0.6-0.8 mm diam; ostiole carbonized laterally; columella simple, 150-250 µm thick, carbonized; hymenium 110-130 µm high; ascospores hyaline, transversely septate, 8 per ascus, 3-5 X 11-20 µm, 3-6 loculate, I + reddish violet.

Chemistry: Thallus K + yellow, P + red; 'cinchonarum' unknown present; medulla pale orange.

Specimen examined: South Andaman, Wimberliganj, Kalatang-85.182. Wandoor, Alexandria island- 85.1147.

Distribution: Singapore, India.

This species is close to *Ocellularia cavata* (Ach.) Müll. Arg. in the peculiar chemistry and morphology of ascocarps but *O. cavata* has larger ascospores (6-8 X 25-43 µm).

Phaeotrema lacteum (Krempelh.) Müll. Arg. in *Flora, Jena,* 70: 398 (1887). (Fig. 13)
Thelotrema lacteum Krempelh. in Nyl. in *Flora, Jena, 47: 269 (1864).*

Thallus whitish to pale yellowish, smooth, medulla 15-30 µm thick, hypophloeodal; apothecia numerous, solitary, emergent, 0.6-0.85 mm diam; disc wide open, white to ashy white pruinose, 200-500 µm across; thalline exciple suberect to erect, inner exciple pulling away from the thalline exciple, free, reddish brown; hymenium 140-160 µm high, 300-550 µm broad; ascospores brown, transversely septate, 4 per ascus, 10-12 X 37-50 µm, 10-15 loculate.
Chemistry: Thallus K-, P-; lacking lichen substances.
Specimen examined: South Andaman, Baratang island, Nilambur-85.484.
Distribution: United States, West Indies, Central America, Kenya, Mozambique, South Africa, Sri Lanka, Japan, New Guinea, Australia, Solomon islands, New Caledonia, Polynesia, Hawaii islands, India.

Thelotrema glaucopallens Nyl., *Ann. Sci. nat. (Bot.)* IV, II: 327 (1863). (Fig. 14)

Thallus light greenish gray, smooth, shiny, medulla 330-400 µm thick, studded with crystals, corticated, epiphloeodal; apothecia numerous, solitary, immersed to slightly raised, 0.2-0.35 mm diam; ostiole round, flush to barely raised, off-white to pale coloured annulate rim, 120-170 µm across; exciple fused, non-carbonized to weakly carbonized at the apex only; hymenium 90-110 µm high, 150-180 µm broad; ascospores hyaline, muriform, 8 per ascus, 7-9 X 22-25 (29.4) µm, 1-3 X 7-10 loculate, I-.
Chemistry: Thallus K + yellow, P + orange; stictic and constictic acids present.
Specimens examined: South Andaman, Chidya Tapu- 84.51, 66, 74(a), Wimberliganj, Kalatang- 85.94, 128.
Distribution: Panama, Dominica, Guatemala, Guyana, Venezuela, Trinidad, Tanzania, Ivory Coast, Union of South Africa, Philippines, India.

Thelotrema guptei, sp. nov. (Fig. 15)

Thallus albo-cinereus, inaequalis, crassus, pro parte hypophloeodes; apothecia rara, dispersa, solitaria, semi-emergentia vel emergentia, 0.8 - 1.3 mm diametro; ostiolum rotundatum, apertum, 0.35-0.45 mm diametro; excipulum connatum, intus carbonaceum; columella cylindrica, carbonacea, 80-120 µm crassa; hymenium 350-400 µm altum; sporae 1: nae, incolores, murales, 21-33 X 121-172 µm, I + caerulescentes.

Thallus whitish gray, uneven, cracked, medulla 60-90 µm thick, crystalloid, corticated, partly hypophloeodal; apothecia few, scattered, solitary, semi-emergent to emergent, 0.8-1.3 mm diam; ostiole open, 350-450 µm across; exciple carbonized; columella simple, 80-120 µm thick, carbonized; hyme-

350-400 µm high; ascospores hyaline, muriform, 1 per ascus, 21-33 X 121-172 µm, I + deep violet.

Chemistry: Thallus K-, P-; lacking lichen substances.

Typus: India, Andaman islands, South Andaman, Port Mount, leg. P.G. Patwardhan and M.B.Nagarkar, 14 February 1985, 85.21 (AMH- *holotypus*, US- *isotypus*).

Specimen examined: South Andaman, Port Mount- 85.21.

Thelotrema depressum Mont., the only comparable species has larger (upto 2 mm diam.), heavily carbonized ascocarps constricted at the base.

This new species is named after Mr. S.C.Gupte, former Conservator of Forests, Andaman and Nicobar circle.

Thelotrema massalongoi (Mont.) Zahlbr., *Cat. Lich. Univ.*, **2**: 624 (1924).
(Fig. 16)
Ascidium massalongoi Mont., *Ann. Sci. nat. (Bot.)* IV, **14**: 174 (1860).

Thallus pale yellowish gray, smooth to finely warty, medulla 100-120 µm thick, studded with crystals, dense cortex, epiphloeodal; apothecia numerous, solitary to group of 2 to 4, strongly emergent, constricted at the base, ascidioid, 1-1.5 mm diam; ostiole round, depressed, surrounded by a strongly raised rim, 400-700 µm across; exciple carbonized laterally; columella simple, base broader than the apex, tip white to off-white pruinose evident through the pore, 120-200 µm thick; hymenium 300-400 µm high; ascospores hyaline, muriform, 1 per ascus, 25-33 X 127-207 µm, I + deep violet.

Chemistry: Thallus K + yellow, P + orange; salacinic acid present.

Specimens examined: South Andaman, Baratang island, Wrafter's Crick- 85.646, 650, 651, 652, 653.

Distribution: India, Sabah, Sri Lanka, Malaya, Philippines, Japan, Solomon islands, Australia.

Thelotrema polillense Vainio in *Suom.Tiedeakat. Toim. A*, **15**(6): 180 (1921).
(Fig. 17)

Thallus pale greenish gray, smooth medulla 60-100 µm thick, epiphloeodal; apothecia numerous, solitary, semi-emergent to emergent, 0.8-1.2 mm diam; ostiole open, brown rim, pore gaping, 350-500 µm across; exciple carbonized laterally; columella very wide, 400-600 µm thick, carbonized, becoming divided at maturity, no hymenium part develop in the dividing region, white pruinose at the tip; hymenium 70-90 µm high; ascospores hyaline, muriform, 8 per ascus, 4.8-6.4 X 11-17 µm, 4-6 transverse locules, 2 longitudinal locules, I + violet.

Chemistry: Thallus K-, P + yellow; psoromic acid present.

Specimen examined: South Andaman, Wimberliganj, Kalatang- 85.79.

Distribution: Sri Lanka, New Caledonia, Philippines, India.

The columella in the Andaman material is vertically furrowed but no asci or paraphyses develop in the furrows.

Thelotrema recurvum G. Salisb., *Rev. Bryol. et Lichenol.*, **38**: 285 (1972).
(Fig. 18)

Thallus whitish gray, smooth, medulla 30-50 µm thick, crystalloid, partly hypophloeodal; apothecia numerous, solitary, rounded to elongated, semi-emergent, chroodiscoid, 1-2.5 mm diam; disc wide open, white to ashy pruinose; exciple free, periphysoids, thalline margin recurved, non-carbonized; hymenium 100-140 µm high, 600-1200 µm broad; ascospores hyaline, muriform 2/4 per ascus, 15-20 X 40-68 µm, I + deep yellow.

Chemistry: Thallus K-, P-; lacking lichen substances.

Specimen examined: Andaman island, South Andaman, Wandoor, Alexandria island- 85.1146.

Distribution: Philippines, India.

ACKNOWLEDGEMENTS

We are grateful to Mr. S.C.Gupte, Ex. Conservator of Forests, Andaman and Nicobar Islands, India for his active interest in the field work and to Dr. Mason E.Hale, Smithsonian Institution, Washington D.C. for critically going through the manuscript and valuable suggestions.

We are also grateful to Department of Science and Technology, New Delhi for financial support.

LITERATURE CITED

Hale, M.E. 1974. Morden-Smithsonian Expedition to Dominica: The Lichens (Thelotremataceae). *Smithsonian Contr. Bot.*, **16**: 1-46.

Hale, M.E. 1978. A Revision of the Lichen Family Thelotremataceae in Panama. *Smithsonian Contr. Bot.*, **38**: 1-60.

Hale, M.E. 1981. A Revision of the Lichen Family Thelotremataceae in Sri Lanka. *Bull. Br. Mus. nat. Hist.* (Bot.), **8** (3): 227-332.

Jatta, A. 1905. Licheni Esotici dell'Erbario Lavier reccolti nell'Asia meridionale, nell'Oceania, nell'Biasile e nell Madagascar.. *Malpighia*, **19**: 162-186.

Nylander, W. 1873. Lichenes insularum Andaman. *Bull. Soc. Linn.Normand.*, II, **7**: 162-183.

Singh, A. 1979. The lichen flora of India with special reference to Andaman Islands. *Progress in Plant Research, Silver Jubilee Publication, N.B.R.I.*, **1**: 39-56 (T.N. Khoshoo and P.K. Nair, Eds.).

Thothathri, K. 1960. Studies on the flora of the Andaman Islands. *Bull. bot. Surv. India*, **2** (3 & 4): 357-373.

Thothathri, K. 1962. Contributions to the flora of the Andaman and Nicobar Islands. *Bull. bot. Surv. India*, **4** (1-4): 281-296.

Williamson, M. 1984. Sir Joseph Hooker's Lecture on Insular Floras. *Biol. J. Linn. Soc.*, **22**: 59-77.

Explanation of figures 1-18: 1. *Leptotrema elachistoteron* (85. 237); 2. *L. nuwarense* (85. 1108b); 3. *L. pertusarioides* (85. 1115, Holotype-AMH); 4. *L. reclusum* (85. 1217); 5. *Ocellularia allosporoides* (85. 59); 6. *O. berkeleyana* (85. 1065); 7. *O. diacida* (85. 33); 8. *O. olivacea* (85. 222); 9. *O. pycnophragmia* (85. 489); 10. *O. terebrans* (85. 63); 11. *O. wandoorensis* (85. 1180, Holotype-AMH); 12. *O. xanthostromiza* (85. 182); 13. *Phaeotrema lacteum* (85. 325); 14. *Thelotrema glaucopallens* (85. 51); 15. *T. guptei* (85.21, Holotype-AMH); 16. *T. massalongoi* (85.646); 17. *T. polillense* (85. 79); 18. *T. recurvum* (85. 1146). Scale in mm.

MYCOTAXON

Vol. XXVII, pp. 83-86 October-December 1986

Hyphomucor, a new genus in the Mucorales for Mucor assamensis.

M.A.A. Schipper,

Centraalbureau voor Schimmelcultures,
P.O. Box 273, 3740 AG Baarn, The Netherlands.

Three strains identified as *Mucor assamensis* by Mrs Joyce Lunn of CMI were studied. Unlike *Mucor* spp, these isolates produced a layer of aerial hyphae on which sporangiophores were formed; the latter heavely branched with almost perpendicular branches.
The production of sporangiophores from aerial hyphae was not mentioned in the original description. The strains are otherwise similar to "Mucor" assamensis. The type culture of *Mucor assamensis*, isolated from forest soil of Tezpur, Assam, was not available.
A new genus is proposed to accomodate "Mucor assamensis".

Hyphomucor Schipper & Lunn, gen. nov.

Sporangia multispora, anapophysata, columellata; sporangiophora ramosa, oriuntur ex hyphae aeriae vel superficialibus, zygosporae ignotae.

type species *Hyphomucor assamensis* (Mehrotra & Mehrotra) Schipper & Lunn = *Mucor assamensis* B.S. Mehrotra & B.R. Mehrotra - Sydowia 23: 184. 1969.

Multispored, non-apophysate, columellate sporangia are borne on branched sporangiophores, arising from aerial hyphae and superficial hyphae. Zygospores are unknown.

The genus differs from Mucor by the production of sporangiophores on aerial hyphae, from Mortierella by distinctly columellate sporangia, from Thermomucor and Rhizomucor in the absence of growth above 36°C. The genus is distinguished from Absidia, Actinomucor and Rhizopus by the absence of distinct stolons and rhizoids. Simple sporangiophores as seen in Rhizopus and apophysate sporangia as seen in Absidia, do not occur in Hyphomucor.

Hyphomucor assamensis, (Mehrotra & Mehrotra) Schipper & Lunn comb. nov.
≡ Mucor assamensis B.S. Mehrotra & B.R. Mehrotra.

The following description is based on CBS 415.77, on OA at 25°C.
Colony greyish, with abundant white, sterile, aerial mycelium and blackish sporangia.
Sporangiophores straight or recurved, arising from thin, branched, aerial hyphae, rarely from superficial hyphae, glassy white to brownish, darkest just below the sporangia, repeatedly branched sympodially, narrow at the base, widening towards the sporangium, up to 20 um wide. Sporangia globose, mostly up to 75 um diam, occasionally up to 100 um, white to black, either dry and powdery in appearance or surrounded by moisture.
Columellae sessile, applanate or conical, some with a blunt projection at the top, bluish, collars small or absent.
Sporangiospores (sub)globose, slightly roughened in outline, with granular contents, 4-6 (8)um diam.
Zygospores unknown.
Influence of temperature: no growth at 36°C and above, nor at 6°C and below. Growth, no sporulation at 33°C; growth and sporulation between 12 and 30°, optimal at about 24°C.
Influence of medium: mature sporangia were produced on beerwort agar, PDA, cherry agar, V8-agar and OA. Colonies on PDA at 24°C were rather diffuse, allowing observation of sporangiophore development.

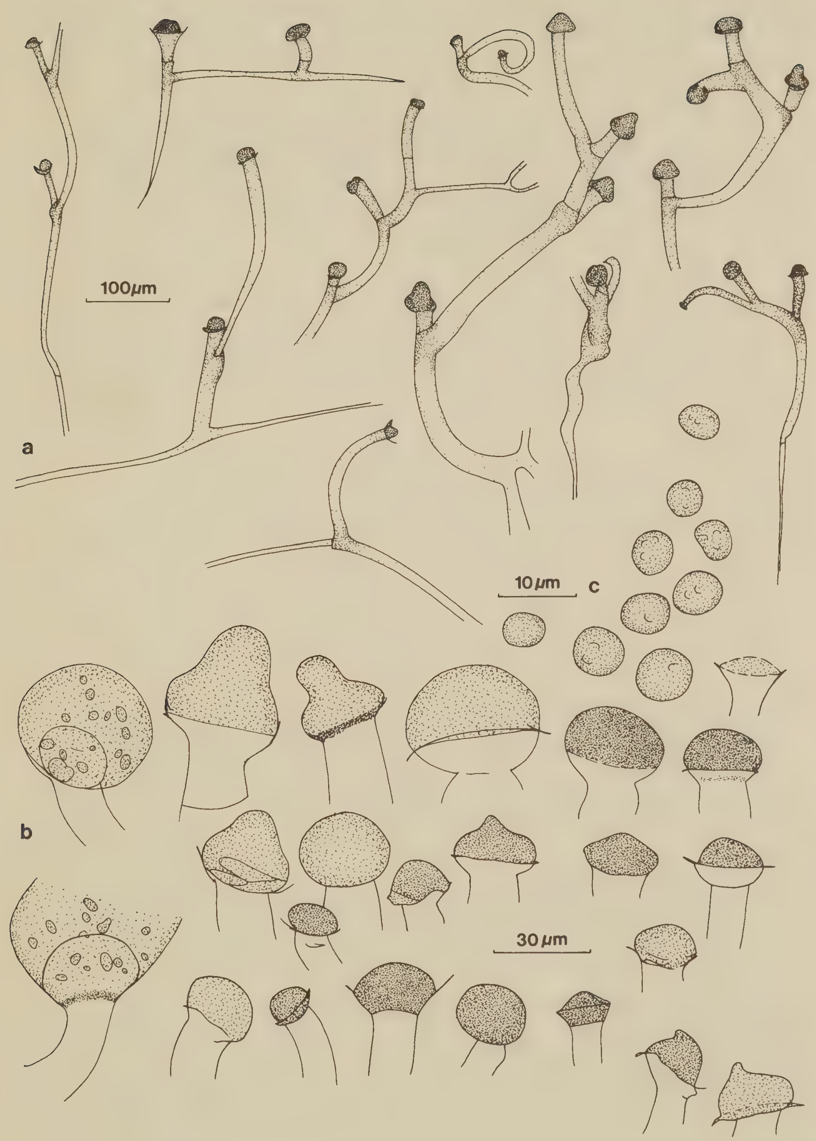

100μm
a
10μm
c
b
30μm

Fig. 1. Hyphomucor assamensis comb. nov.-
a. sporangiosphores.-
b. columellae.- c. sporangiospores.

Influence of light: insignificant.

Material examined

CBS 415.77 = IMI 210192, an Indian isolate identification (G. Satyanarayana)
CBS 254.85 = IMI 213883, ex Burmannia sp, Kuala Lumpur, Malaysia (N. Ariffin, sub 56)
CBS 253.85 = IMI 227326, ex soil, Sri Lanka (Dr. Coomaraswamy, sub 5)
A fourth strain, isolated from tropical forest soil, Sri Lanka by R.N. de Fonseca was available as an herbarium specimen only (IMI 224379, *Mucor* tax. sp. II).

Mating experiments

No sexual reactions were observed in contrasts between the strains on various media and temperatures.

Discussion

Hyphomucor assamensis resembles *Thermomucor indicae-seudaticae*, but differs in being mesophilic and in the production of non-apophysate sporangia on sporangiophores arising from aerial hyphae.

Acknowledgements

I want to thank Dr. A. Onions and Dr. Paul Kirk, CMI, for reading the manuscript; Dr. J.A. Stalpers for preparing the latin diagnosis.

MYCOTAXON

Vol. XXVII, pp. 87-92 October-December 1986

METARHIZIUM FLAVOVIRIDE VAR. *MINUS*, VAR. NOV., A PATHOGEN OF PLANT- AND LEAFHOPPERS ON RICE IN THE PHILIPPINES AND SOLOMON ISLANDS

Michiel C. Rombach*
Insect Pathology Resource Center
Boyce Thompson Institute at Cornell University
Tower Road, Ithaca, New York 14853, USA

Richard A. Humber
USDA-ARS Plant Protection Research Unit
Boyce Thompson Institute at Cornell University
Tower Road, Ithaca, New York 14853, USA

Donald W. Roberts
Insect Pathology Resource Center
Boyce Thompson Institute at Cornell University
Tower Road, Ithaca, New York 14853, USA

Metarhizium flavoviride Gams & Rozsypal var. ***minus*** var. nov. is described from the brown planthopper, *Nilaparvata lugens* Stål (Homoptera, Delphacidae), on rice in the Philippines and the Solomon Islands and from the zig-zag leafhopper, *Recilia dorsalis* (Motschulsky) (Homoptera, Cicadellidae), in the Philippines. The new variety has also been collected on a grasshopper in the Galápagos Islands.

The conidia of the new variety are smaller (mostly 4.5-7 x 2-3 µm) and more consistently ellipsoidal to ovoidal than those of *M. flavoviride* var. *flavoviride* [(6.5-)7-9[-11] x 4.5-5.5 µm]. The new variety may form synnemata in culture.

At present, three species of *Metarhizium* are recognized: Most authors have followed Tulloch (1976) in accepting *M. anisopliae* (Metschn.) Sorok. (with cylindrical phialides bearing chains of cylindrical conidia that usually adhere laterally to form columnar conidial columns) and *M. flavoviride* Gams & Rozsypal (with narrowly clavate phialides bearing chains of ovoid or ellipsoidal conidia that typically adhere in parallel masses). Rombach et al. (1986b) are restoring the name *Metarhizium album* Petch for a pathogen of Asiatic homopterans that forms clavate phialides with nonadherent chains of white to brown, ellipsoid to ovoid conidia.

---

* Seconded to Department of Entomology, International Rice Research Institute, P.O. Box 933, Manila, Philippines.

Metarhizium flavoviride is primarily an entomogenous species reported from curculionid beetles (Gams & Rozsypal 1973; Marchal 1977), from a grasshopper (Evans & Samson 1982), and from agricultural soils in Germany and the Netherlands (Gams & Rozsypal 1973). This species has been studied as a specific pathogen of black vine weevils, *Otiorrhynchus sulcatus* F. (Marchal 1977; Soares et al. 1983; Poprawski et al. 1985a) and of the onion root maggot, *Delia antiqua* (Meigen) (Poprawski et al. 1985b). The small-spored variety described below causes natural epizootics of the brown planthopper, *Nilaparvata lugens* Stål, and of the zig-zag leafhopper, *Recilia dorsalis* (Motschulsky), on rice in the Philippines and Solomon Islands. Field populations of brown planthoppers can be infected by sprayed applications of the small-spored variety (Rombach et al. 1986a).

Metarhizium flavoviride Gams & Rozsypal (1973) is characterized by the formation of sporodochia bearing clavate phialides (9-14 x 3-4.5 µm) and chains of large ellipsoidal conidia (Fig. 1a); the conidial masses of this species are pale green to distinctly yellow-green. Cultures of *Metarhizium flavoviride* are slow growing, flat, and slow to produce conidia. The ovoid to ellipsoid conidia and clavate phialides are the major diagnostic characters which separate *M. flavoviride* from *M. anisopliae* with its distinctly cylindrical conidia and cylindrical phialides.

In recent years, numerous isolations identified as *Metarhizium flavoviride* were made from plant- and leafhoppers on rice in Asia (Fig. 2a). Most of these isolates are preserved in liquid nitrogen at the Collection of Entomopathogenic Fungi (ARSEF), USDA-ARS Plant Protection Research Unit (Boyce Thompson Institute, Ithaca, New York).

On the plant- and leafhoppers (Fig. 1b), *Metarhizium flavoviride* shows a slightly different morphology from that originally described for *M. flavoviride* by Gams & Rozsypal (1973), most notably in the smaller dimensions (Table 1) and more consistently ovoid shape of the conidia. In artificial culture (Fig. 1c), the characteristics are slightly more variable. Tulloch (1976) separated the varieties *M. anisopliae* var. *anisopliae* and *M. anisopliae* var. *majus* (Johnston) Tulloch* mainly by the shape and dimensions of their conidia. It is appropriate, therefore, to expand the concept of *M. flavoviride* defined by Gams & Rozsypal (1973) to accommodate these Asiatic isolates from plant- and leafhoppers on rice in a new

---

* This is an obligatory orthographic correction of the varietal name usually cited as *M. anisopliae* var. *major*.

TABLE 1. Conidial measurements of *Metarhizium flavoviride*. Isolates (listed by ARSEF numbers) were grown on Sabouraud dextrose agar + 1% yeast extract at room temperature. Sizes expressed as mean ± standard deviation for 75 conidia measured in lactophenol/aniline blue.

ARSEF	HOST/SOURCE	COUNTRY	SIZE (µm)
	M. flavoviride var. *flavoviride*		
2133[a]	*Ceutorrhynchus macula-alba*	Czechoslovakia	7-9(-11) x 4.5-5.5[b]
1184	*Otiorrhynchus sulcatus*	France	8.5 ± 1.1 x 3.8 ± 0.5
2025	agricultural soil	Fed. Rep. Germany	8.7 ± 2.9 x 4.5 ± 0.6
2026	agricultural soil	Netherlands	9.2 ± 0.9 x 5.4 ± 0.6
	M. flavoviride var. *minus*		
2037[a]	*Nilaparvata lugens*	Philippines	4.6 ± 0.7 x 2.7 ± 0.3
1099	*Nilaparvata lugens*	Philippines	4.6 ± 0.6 x 2.3 ± 0.4
1547	*Recilia dorsalis*	Philippines	5.2 ± 0.8 x 2.6 ± 0.4
1764	*Nilaparvata lugens*	Solomon Islands	5.4 ± 0.7 x 2.6 ± 0.4
1768	*Nilaparvata lugens*	Solomon Islands	5.9 ± 0.8 x 2.5 ± 0.4
2023	Acridid grasshopper	Galápagos Islands	4.9 ± 0.7 x 2.6 ± 0.4

[a] Type strain of variety.

[b] From Gams & Rozsypal (1973); the type strain subculture examined here, as noted by Gams and Rozsypal, was unpigmented and produced few typical phialides but many extremely variable clavate to cylindrical conidia, 8.6 ± 1.7 x 3.0 ± 0.5 µm.

variety of this species; these isolates consistently produce smaller conidia and sometimes form fasciculate masses of hyphae (synnemata) in artificial culture (Fig. 2b). Varieties of this species are characterized primarily by conidial dimensions.

Metarhizium flavoviride Gams & Rozsypal var. ***flavoviride***, *Acta Bot. Neerl.* **22**, 518-521 (1973). FIG. 1A

Cultures Examined: ARSEF 2133 (ATCC 32969 < CBS 218.56), ex type culture, from larvae/pupae of *Ceutorrhynchus macula-alba*, Brno, Czechoslovakia, 1956. ARSEF 1184 (INRA MF-88 = CBS 700.74), from *Otiorrhynchus sulcatus*, Brittany (France), January 1974. ARSEF 2025 (CBS 125.65), from soil under *Brassica oleracea*, Kiel-Kitzeberg, Fed. Rep. Germany, 1963 or 1964. CBS 380.73, from soil under *Brassica oleracea*, Kiel-Kitzeberg, Fed. Rep. Germany, 1963 or 1964. ARSEF 2026 (CBS 473.73), from agricultural soil, coll. J. W. Veenbaas-Rijks, Wageningen, Netherlands, 1973.

Metarhizium flavoviride Gams & Rozsypal var. ***minus*** Rombach, Humber, & Roberts, **var. nov.** FIGS. 1B, 2

Morphologiae conidiophororum, phialidium clavatarum, conidiorum ellipsoideorum ovoideorum, et habitu in cultura Metarhizium flavoviride simulant, autem conidia viridi-grisea parviora, 4.5-7 x 2-3 µm, et (in cultura) synnemata albida laxe fasciculata sparsim fecunda formans.

Holotype: **CUP 61454**, on *Nilaparvata lugens* Stål, experimental rice field, International Rice Research Institute, Los Baños, Philippines, leg. M.C. Rombach, 5 November 1985.

Isotypes: **CBS**, **IMI**, and at the USDA-ARS Plant Protection Research Unit (Ithaca, New York).

Cultures Examined: ARSEF 2037, type culture isol. from holotype, leg. M.C. Rombach, November 1985. ARSEF 543, from greenhouse culture of *Recilia dorsalis* (Motschulsky), International Rice Research Institute, Low Baños, Laguna, Philippines, D. W. Roberts, August 1980. ARSEF 1547, from *Recilia dorsalis* (Motschulsky), Pangasinan, Luzon, Philippines, leg. R. M. Aguda, September 1982. ARSEF 1763 through 1773 (inclusive), from *Nilaparvata lugen* s Stål on rice, Guadalcanal Plains, Guadalcanal, Rep. Solomon Islands, coll. by D. T. Ho, isol. by M. C. Rombach, February 1985. ARSEF 2023 (CBS 544.81, as *M. flavoviride*) from Acrididae (Orthoptera), Santa Fé Island, Galápagos Islands, coll. H. C. Evans, 1981. Numerous cultures from *Nilaparvata lugens* on rice from the International Rice Research Institute, Los Baños, Philippines.

The branched conidiophores, clavate conidiogenous cells, and long chains of ellipsoidal conidia of *M. flavoviride* var. *minus* generally resemble those of *M. flavoviride* Gams & Rozsypal (1973) but differ in their dimensions. The conidial chains of both varieties aggregate into columnar masses similar to those of *M. anisopliae*. The conidiogenous cells of var. *minus* are 8.4 ± 1.2 x 2.8 ± 0.3 µm (on Sabouraud dextrose

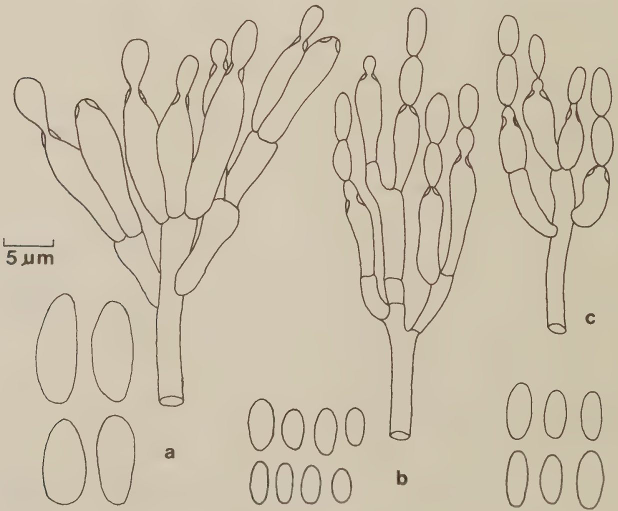


Fig. 1. Conidiophore and conidia of (a) *Metarhizium flavoviride* var. *flavoviride* (isolate CBS 380.73a), (b) *M. flavoviride* var. *minus* on the brown planthopper, and (c) in culture, ARSEF 1547.

agar + 1% yeast extract) whereas those of var. *flavoviride* are 9-14 x 3–4.5 µm (from malt extract and oatmeal agars). The conidia of var. *minus* are 4.5-7 x 2-3 µm and dull grey-green in mass (with no significant hint of yellow pigments); the larger (6.5-11 x 3.5-5 µm) conidia of var. *flavoviride* are usually yellow-green. Conidial sizes in several strains of these varieties are listed in Table 1. Because conidia of both barieties tend to become slightly narrower after repeated transfers on artificial media; isolates should be frozen in liquid nitrogen or lyophilized at the earliest chance. In culture, *M. flavoviride* var. *minus* may produce synnemata up to 10 mm high (Fig. 2b) rather than the more usual flat, stroma-like sporodochia. These synnemata often remain white and sterile or may show fertile patches.

Metarhizium flavoviride var. *minus* resembles *M. album* Petch in the morphologies of the conidiophores, clavate phialides, and conidia. These species differ in their conidial colors since *M. album* is whitish-brown (with no hint of green pigmentation). Also, the flat, smooth hymenial surface with conidial chains adhering in large columns produced by *M.flavoviride* var. *minus* differs markedly from the raised sporodochial masses of hyphal bodies produced by *M. album*. The recognized species of *Metarhizium* are also distinguished unambiguously by comparisons of the electrophoretic mobility of their various isoenzyme systems.

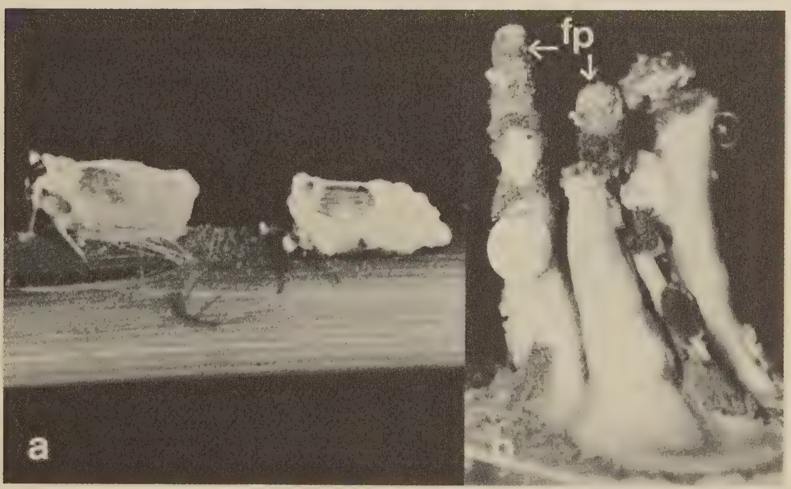


Fig. 2. *M. flavoviride* var. *minus*. (a) Infecting brown planthopper; insect on right is an early stage of postmortem development with protruding white mycelium; specimen on the left exhibits a darker fertile patch. (b) Synnemata of ARSEF 1547 in culture; note apical fertile patches (fp). Both micrographs, x 7.

To date, the small-spored variety of *M. flavoviride* has been collected from plant- and leafhoppers on rice in the Philippines and Solomon Islands; it was absent from extensive collections of fungi from auchenorrhynchid hosts from rice in South Korea, India, and Sri Lanka. A collection of *Metarhizium flavoviride* on a grasshopper from the Galápagos Islands (Evans & Samson 1982) also belongs to var. *minus* (see Table 1). Clearly, this variety may prove to be a much more widely distributed and important pathogen of insects than is now apparent.

Acknowledgments

We thank Dr. B.M. Shepard for his continuous encouragement; Maureen Rombach for preparing the drawings; the Curators at the CBS and ATCC for providing cultures; Dr. D.T. Ho for the Solomon Islands collections; Drs. W. Gams, W.B. Kendrick, R.P. Korf, and K.A. Seifert for their constructive reviews: and the Office of the Science Advisor of the US Agency for International Development for partly supporting this work.

References

EVANS, H. C., & R. A. SAMSON. 1982. Entomogenous fungi from the Galápagos Islands. *Can. J. Bot.* **60**: 2325-2333.

GAMS, W., & J. ROZSYPAL. 1973. *Metarhizium flavoviride* n.sp. isolated from insects and from soil. *Acta Bot. Neerl.* **22**: 518-521.

MARCHAL, M. 1977. Fungi Imperfecti isolés d'une population naturelle d'*Otiorrhynchus sulcatus* Fabr. (Col.; Curculionidae). *Rev. Zool. Agric. Pathol. Végét.* **76**: 101-108.

POPRAWSKI, T. J., M. MARCHAL, & P. H. ROBERT. 1985. Comparative susceptibility of *Otiorrhynchus sulcatus* and *Sitona lineatus* (Coleoptera: Curculionidae) early stages to five entomopathogenic Hyphomycetes. *Environ. Entomol.* **14**: 247-252.

POPRAWSKI, T. J., P. H. ROBERT, I. MAJCHROWICZ, & B. BOIVIN. 1985. Susceptibility of *Delia antiqua* (Diptera: Anthomyiidae) to eleven isolates of entomopathogenic Hyphomycetes. *Environ. Entomol.* **14**: 557-561.

ROMBACH, M. C., AGUDA, R. M., SHEPARD, B. M., & ROBERTS, D. W. 1986. Infection of the rice brown planthopper, *Nilaparvata lugens* (Homoptera; Delphacidae) by field applications of entomopathogenic Hyphomycetes (Deuteromycotina. *Environ. Entomol.*: in press.

ROMBACH, M. C., HUMBER, R. A. & EVANS, H. C. 1986. *Metarhizium album* Petch, a pathogen of plant- and leafhoppers of rice. [In prep. for *Trans. Brit. Mycol. Soc.*]

SOARES, G. G., M. MARCHAL, & P. FERRON. 1983. Susceptibility of *Otiorrhynchus sulcatus* (Coleoptera: Curculionidae) larvae to *Metarhizium anisopliae* (Deuteromycotina: Hyphomycetes) at two different temperatures. *Environ. Entomol.* **12**: 1886-1890.

TULLOCH, M. 1976. The genus *Metarhizium*. *Trans. Brit. Mycol. Soc.* **66**: 407-411.

MYCOTAXON

Vol. XXVII, pp. 93-98 October-December 1986

STUDIES ON CHINESE ASCOMYCETES.
3. ASTROSPHAERIELLA LAGENIFORMIS.

JING-ZHU YUE[*] & OVE ERIKSSON[**]

ABSTRACT

Rhynchostoma Karsten is discussed. The correct name for the single species recorded from China, **R. lageniforme** Teng, is **Astrosphaeriella lageniformis** (Teng) J.-z. Yue & O. Eriksson.

INTRODUCTION

About 20 species have been described in **Rhynchostoma** Karsten, and at least five other species have been transferred to the genus from other genera. Some species have been excluded, but the genus is still in need of revision. It is currently classified in the Trichosphaeriaceae, but the type species, **R. minutum** Karsten, is certainly not closely related to **Trichosphaeria** Fuckel. The only species of **Rhynchostoma** that has been described from China is **R. lageniforme** Teng. We have examined original material of this species and compared it with original material of the generic type and some other species in the genus. We found that, in fact, the Chinese fungus has bitunicate asci and belongs in **Astrosphaeriella** H. Sydow & Sydow.

MATERIALS AND METHODS

For details about methods used, see Eriksson & Yue (1985) and Yue & Eriksson (1985).

---

[*] Institute of Microbiology, Academia Sinica, Beijing, China. [**] Institute of Ecological Botany, University of Umeå, S-90187 Umeå, Sweden.

RESULTS

Astrosphaeriella lageniformis (Teng) J.-z. Yue & O. Eriksson comb. nov.
Bas.: **Rhynchostoma lageniforme** Teng, Sinensia 7: 508 (1936)

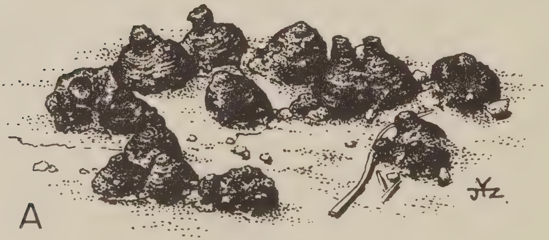
Ascomata scattered - densely aggregated, erumpent and finally almost completely free and with only the flat base lower than the surface of the host, hemispherical or subconical, with uneven surface, ca. 300-500 µm across, with a long, cylindrical or conical beak; ascomal wall ca. 100 µm thick, carbonized, opaque.

Centrum hollow in dry ascomata; hamathecium of anastomosing paraphysoids, ca. 1 µm wide.

Asci numerous, ca. 90 x 14 µm, cylindric clavate, rather short-stalked, bitunicate, with thin ectotunica and rather thin endotunica, without ring structures, 8-spored.

Ascospores (Fig. 1B) ca. 35-40 x 6-7 µm, narrowly fusiform - clavate, somewhat inequilateral, medially 1-septate, upper hemispore slightly broader, hyaline at first, then pale brown, smooth, without distinct perispore.

Coll.: China, Hainan Prov., Yen-sheng, on **Cocos nucifera**, 15.II.1934, leg. S.Q. Deng n. 921, det. S.C. Teng (CUP-CH177).



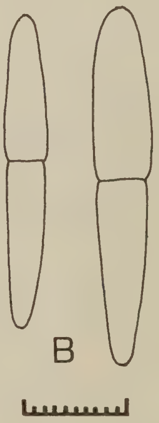


Fig. 1. **Astrosphaeriella lageniformis.** (A). Ascomata. (B). Ascospores; hyaline, immature spore (left) and pale brown, mature spore (right). - Coll.: CUP-CH177. Magn.: (A). x22. (B). scale = 10 µm.

DISCUSSION

Karsten (1870) distributed **Rhynchostoma minutum** n. gen. et sp. in his exsiccatum Fungi Fenn. Exs., n. 950. The short generic diagnosis in the lable reads "Perithecia rostrata; sporae fuscae, uniseptate". We have examined the exsiccatum preserved in Helsinki (H). It consists of two small pieces of old wood of **Juniperus communis** with numerous, scattered ascomata of **R. minutum**. They are small, globose, immersed - almost free. The beak is broken at the base in almost all ascomata in this collection, only in a few it is broken at the middle. We saw only one ascoma with an unbroken beak. The ascomata (incl. the beak) appear black under the dissecting microscope.

Karsten (1890: 178) described another species with larger ascomata, **R. rubrocinctum**. Petrak and H. Sydow (1923: 375) have given a detailed description of this species. We have studied semithin sections of an ascoma from a Swedish collection (Torne Lappmark, Abisko par., Pålnoviken, on old wood, 15.VI.1984, n. 84940, leg. V. Alstrup, det. O.E., Herb. C), closely agreeing with Petrak & H. Sydow´s description of the species, except that they describe the colour of the beak as "aussen dunkel rotbraun, innen, besonders oben, intensiv rot gefärbt". The ascomata which we have seen (several collections) have apically

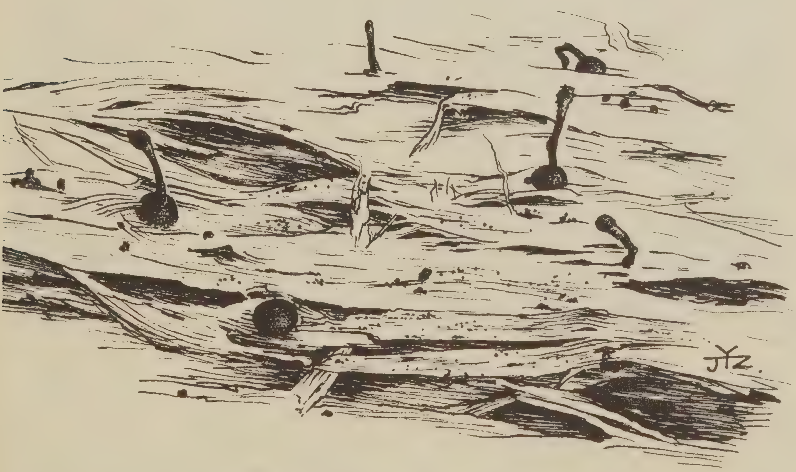


Fig. 2. **Rhynchostoma minutum.** Ascomata on old, naked wood. Coll.: Alstrup n. 84940 (Herb. C). Magn.: x22.

swollen beaks which are usually bright red just below the tip (Fig. 2). The colour is intensive, almost resembling a cigarette glow.

Müller & von Arx (1962: 608) examined original material of **R. minutum** as well as **R. rubrocinctum** and came to the conclusion that the species are identical. They did not mention either the strong red colour and or the surface structure of the ascospores. Several investigators have independently discovered that the spores are provided with spirally arranged ridges (Jing-zhu Yue, Leif Tibell, Geir Mathiassen). Mathiassen (1985: Pl. VId) published a SEM graph of spores from a specimen with beak coloured red in its apical part. We have SEM-graphs of spores from the above mentioned collection (Alstrup, n. 84940) and from the original material of **R. minutum**. The ascospores are very similar (Fig. 3), and Müller and von Arx are most probably right that the two species are identical, and that the correct name for the species is **R. minutum** Karsten. There seems to be a seasonal variation, grading from "minutum type" to "rubrocinctum type" of fruit bodies (L.E. Muhr, in litt.)

The type species of **Rhynchostoma**, **R. minutum**, thus can be characterized as a lignicolous pyrenomycete with globose

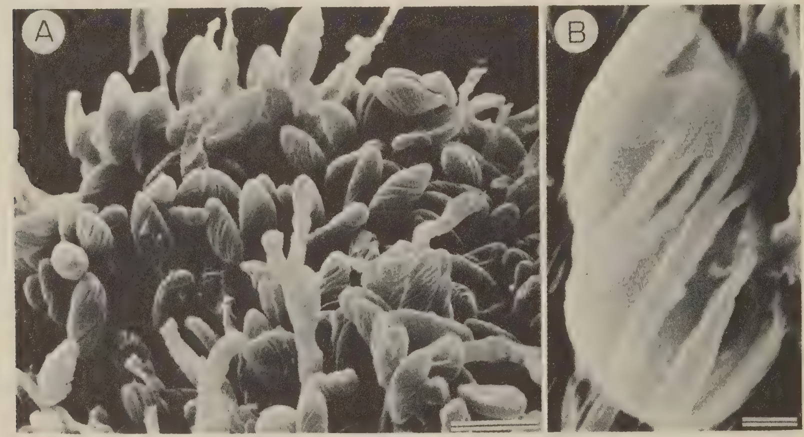


Fig. 3. **Rhynchostoma minutum.** (A). Ascospores and empty asci on the surface of the swollen part of the beak. From a specimen with large ascomata and red-coloured top of the beak. (B). Ascospore from a specimen with small ascomata and black beak. - Coll.: (A). Alstrup n. 84940 (Herb. C). (B). Fungi Fenn. Exs., n. 950 (Herb. H). Magn.: (A). line = 10 µm. (B). line = 1 µm.

perithecia provided with long, apically usually bright red beaks, unitunicate asci with 8, 1-septate spores with spirally arranged ridges. Also worth mentioning is the presence of a hyaline amorphous crust around the beak (thickest at the base), which has previously been observed by Petrak & H. Sydow (l.c.). The original description of **Rhynchostoma** was too vague and most of the species that have been referred to the genus are alien elements. **Rhynchostoma lageniforme** Teng has hemispherical - subconical ascomata with a beak and 1-septate ascospores, but there are numerous important differences, for instance, the ascomal wall is very dark-coloured. The centrum consists of paraphysoids and bitunicate asci with elongate-fusiform, smooth ascospores, and it has to be transferred to the genus **Astrosphaeriella** H. Sydow & Sydow in Melanommatales.

The genus **Astrosphaeriella** was monographed by Hawksworth (1981). He accepted 4 species, one of them, **A. aosimensis** Hino & Katumoto, on leaf stalks of **Livistona** (Arecaceae). **Rhynchostoma lageniforme** was described from leaf stalks of **Cocos nucifera** (Arecaceae). The ascospores are quite similar to those of **A. aosimensis**, but the ascomata are covered by host epidermis in that species, while erumpent in **R. lageniforme**. It is possible that the two taxa are substrate forms of one and the same species, the correct name of which would be **A. lageniformis** (Teng) J.-z. Yue & O. Eriksson. However, for the time being, we suggest that they are kept separate.

*It is very remarkable that ascospores with almost exactly the same surface structure and ontogeny are known in Caliciales (Tibell, pers. comm.; see Tibell 1975: 76). It is difficult to find a better example of how dangerous it is to base a classification on one criterion only. In this very case we know from other characters that **Rhynchostoma** and the Caliciaceae are taxonomically far from each other.

ACKNOWLEDGEMENTS

The authors are grateful to Academia Sinica (Beijing), the Swedish Institute (Stockholm), and the Natural Science Research Council (Stockholm) for financial support of our work. We thank Prof. Dr. D.L. Hawksworth, Mr. L.E. Muhr, and Dr. L. Tibell for valuable information, Dr. L. Holm and Dr. V. Shindler for reading the manuscript, and Dr. V. Alstrup and the curators of CUP, H and UPS for the loan of material.

LITERATURE CITED

ERIKSSON, O. & YUE, J.-Z. 1985. Studies on Chinese ascomycetes. 1. Phaeosaccardinula dictyospora. - Mycotaxon 22: 269-280.

HAWKSWORTH, D.L. 1981. Astrosphaeriella Sydow, a misunderstood genus of melanommataceous pyrenomycetes. - Bot. J. Linn. Soc. 82: 35-59.

HINO, I. & KATUMOTO, K. 1956. Notes on fungi from western Japan (1). - Bull. Fac. Agric., Yamaguti Univ. 7: 257-274.

KARSTEN, P.A. 1890. Fragmenta mycologica. XXX. - Hedwigia 29: 176-179.

MATHIASSEN, G. 1985. Pyrenomyceter (Ascomyceter) på Salix i Troms. - Inst. biol. geol., Univ. Tromsø.

MüLLER, E. & ARX, J.A. VON 1962. Die Gattungen der didymosporen Pyrenomyceten. - Beitr. Krypt.-Fl. Schweiz 11(2): 1-922.

PETRAK, F. & SYDOW, H. 1923. Kritisch-systematische Originaluntersuchungen über Pyrenomyceten, Sphaeropsideen und Melanconieen. I. - Ann. Mycol. 21: 349-384.

TENG, S.-Q., 1936. The mycoflora of China (2). - Sinensia 7: 490-527.

TIBELL, L. 1975. The Caliciales of boreal North America. - Acta Univ. Upsal. 21: 1-136.

YUE, J.-Z. & ERIKSSON, O. 1985. Studies on Chinese ascomycetes. 2. Sinodidymella verrucosa. - Mycotaxon 24: 293-300.

摘 要

本文讨论了嘴球壳属 (Rhynchostoma Karsten). 报道自中国的唯一的种——匏状嘴球壳 (R. lageniforme Teng) 的正确名称为星裂小球壳属 (Astrosphaeriella lageniformis (Teng) J.-z. Yue & O. Eriksson.

MYCOTAXON

Vol. XXVII, pp. 99-106 October-December 1986

THERMOPHYMATOSPORA, A NEW THERMOTOLERANT GENUS OF BASIDIOMYCETOUS HYPHOMYCETES

Shun-ichi UDAGAWA[1], Takeyoshi AWAO[2]

and

Samir K. ABDULLAH[3]

[1] *National Institute of Hygienic Sciences, Kamiyoga 1-chome, Setagaya-ku, Tokyo 158, Japan*
[2] *Central Research Laboratories, Ajinomoto Co., Inc., Suzuki-cho, Kawasaki-ku, Kawasaki-shi 210, Japan*
[3] *Department of Biology, College of Science, University of Basrah, Basrah, Iraq*

SUMMARY

Thermophymatospora fibuligera anamorph gen. et anamorph sp.nov., a basidiomycetous hyphomycete, isolated from cultivated soil at date palm plantation in Iraq is described and illustrated. The fungus is characterized by large, brown, globose, tuberculate conidia and the formation of hyphae with clamp connections. The temperature range for its growth is between 17-48°C, the optimum 35-40°C, no growth occurring at 50°C.

During investigations on thermophilic fungi isolated from a variety of substrates in Iraq by the third author, an unusual soil-borne hyphomycete assignable to a basidiomycete anamorph was encountered. The fungus produces large, brown, thick-walled, tuberculate conidia, suggestive superficially of *Myceliophthora*, but from which it is distinct by the formation of basidiomycete-like hyphae with clamp connections at the septa. As it cannot be accommodated in any basidiomycetous anamorph currently known, the new genus *Thermophymatospora* is here proposed for it. The specimen studied is preserved at the Mycological Herbarium, National Institute of Hygienic Sciences, Tokyo (NHL). The living culture has been placed in the American Type Culture Collection.

Thermophymatospora Udagawa, Awao et Abdullah, anamorph gen. nov.

Fungus thermophilus. Coloniae effusae, brunneae, floccosae vel pulveraceae, plus minusve coactae. Hyphae fertiles hyalinae vel subhyalinae, ramosae, laeves, septatae, fibulis amplis praeditae. Conidiophora micronemata. Conidia holoblastica, acropleurogena super hyphis conidiogenis oriunda, raro intercalaria, plerumque solitaria, continua, flavo-brunnea vel brunnea, globosa vel subglobosa, incrassata, tubercularia cum projecturis prominentibus et costis infernis reticulatis ornata, a cellula conidiogena septo separata. Laccasis praesentes. Teleomorphosis versimile ad Basidiomycetem pertinens.

Species typica: *Thermophymatospora fibuligera* Udagawa, Awao et Abdullah.

Etymology: *thermo*-, from the Greek for warm; *phymatospora*, from the Greek for warty spores.

Colonies spreading, brown, floccose or powdery, more or less felty. Fertile hyphae hyaline to subhyaline, branched, smooth-walled, septate, provided with clamp connections. Conidiophores micronematous. Conidia holoblastic, borne terminally or laterally on conidiogenous hyphae, rarely intercalary, mostly solitary, one-celled, yellowish brown to brown, globose to subglobose, thick-walled, with surface tuberculate with prominent projections interconnected by low straight ridges, separated from the conidiogenous cell by formation of a crosswall. Laccase present. Basidiomycete with unknown teleomorph.

Type species: *Thermophymatospora fibuligera* Udagawa, Awao et Abdullah.

Thermophymatospora fibuligera Udagawa, Awao et Abdullah, anamorph sp.nov. (Figs. 1-6)

Coloniae in agaro 'potato-dextrose' ad 37°C late effusae, constantes ex mycelio basali coacto tenui et conidio abundanti, superne floccosae vel subtomentosae, primo albae, deinde brunneae vel avellaneae vel latericiae; reversum brunneum vel valde callainum.

Hyphae fertiles hyalinae vel subhyalinae, ramosae, tenues vel ex parte incrassae, laeves, 2-6 µm crassae, septatae, ad septum 1-2 fibulis amplis praeditae. Conidiophora micronemata. Hyphae conidiogenae terminales vel laterales, hyalinae, rectae vel flexuosae, simplices vel irregulariter ramosae, plerumque 10-35 × 2-4 μm, tenues, glabrae. Conidia holoblastica, acropleurogena super hyphis conidiogenis oriunda, raro intercalaria, plerumque solitaria, globosa vel subglobosa, (18-)20-24(-25) μm diam (sine tuberculo), primo hyalina, deinde flavo-brunnea vel medibrunnea, incrassata, saepe valde tubercularia cum projecturis usque 1.5-3 μm longis et costis infernis reticulatis ornata, interdum cum vestigio basali et conspicue prominentia apicali, a cellula conidiogena septo 3-4(-5) μm lato separata, facile germinantibus.

Holotypus: cultura NHL 2959, ex solo sativo isolatus est, Saraji Park, Basrah, Iraq, in 25.xi.1984, legit. S.K. Abdullah. In collectione fungorum 'National Institute of Hygienic Sciences (NHL), Tokyo, Japan'.

Etymology:*fibuliger*, from the Latin for clamp-bearing, referring to the formation of clamps.

Colonies on potato-dextrose agar at 37°C spreading broadly, attaining a diameter of 8.5 cm within 7 days, consisting of a very thin basal felt with floccose to subtomentose overgrowth, at first white, becoming brown (Methuen 7E4-5, Kornerup and Wanscher, 1978) or Hazel to Dark Brick (Rayner, 1970) from massed conidia; reverse brown to dark turquoise (Methuen 7E5-24F4-5).Discoloration with 4% or 10% KOH negative. Reactions with α-naphthol and guaiacol positive. Reaction with *p*-cresol negative. Reaction with hydrogen peroxide + pyrogallol negative.

Colonies on oatmeal agar growing as on potato-dextrose agar but less floccose, rather powdery, bearing abundant conidia at center, brown (Methuen 6E6) or Cinnamon to Dark Brick (Rayner, 1970); exudate Fulvous (Rayner, 1970); reverse grayish orange to grayish brown (Methuen 6B3-8F3) or Fuscous Black (Rayner, 1970).

Fertile hyphae hyaline to subhyaline, branched, thin or partially thick, smooth-walled, 2-6 μm wide, regularly provided with 1-2 round clamp connections at each septum. Conidiophores undistinguished from conidiogenous hyphae. Conidiogenous hyphae borne terminally or laterally as side branches on the fertile hyphae, hyaline, straight or flexuous, simple or irregularly branched, usually 10-35 × 2-4 μm, thin, smooth-walled. Conidia holoblastic, borne terminally or laterally, rarely intercalarily on the conidiogenous hyphae, mostly solitary, globose to subglobose, (18-)20-24(-25) μm in diam (without tuberculations), initially hyaline, becoming yellowish brown to mid-brown in age, thick-walled, with surface often markedly tuberculate with projections reaching a maximum length of 1.5-3 μm and interconnected by low straight ridges in reticulate appear-

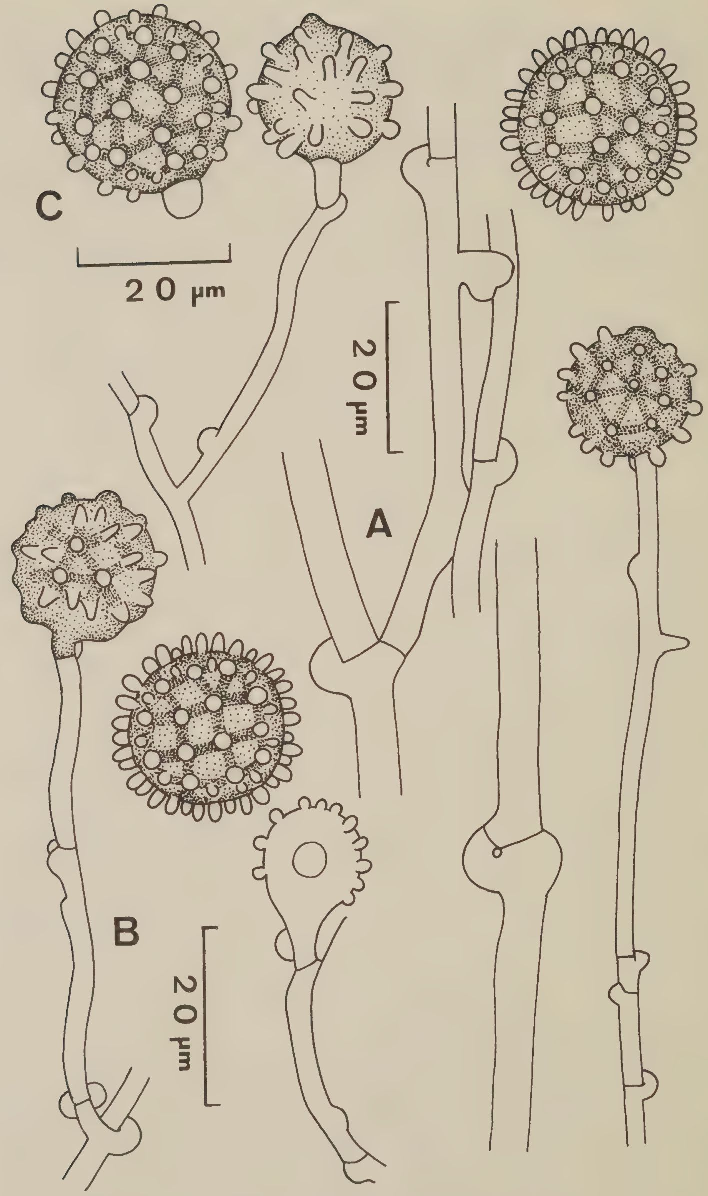

C
20 µm
20 µm
A
B
20 µm

Fig. 1. *Thermophymatospora fibuligera*.
A. Fertile hyphae with clamp connections. B. Conidiogenous hyphae and young conidia. C. Matured conidia.

ance, sometimes with a basal remnant and a prominent apical elongation, separated from the conidiogenous cell by formation of a crosswall, 3-4(-5) µm wide at the base, germinating easily by mean of a single germ tube.

Temperature relations: thermotolerant with optimal growth and conidial formation at 35-40°C (Table 1).

Specimen examined: ex soil at date palm plantation, Saraji Park, Basrah City, Iraq, November 25, 1984, isolated by S. K. Abdullah, NHL 2959 (Holotype).

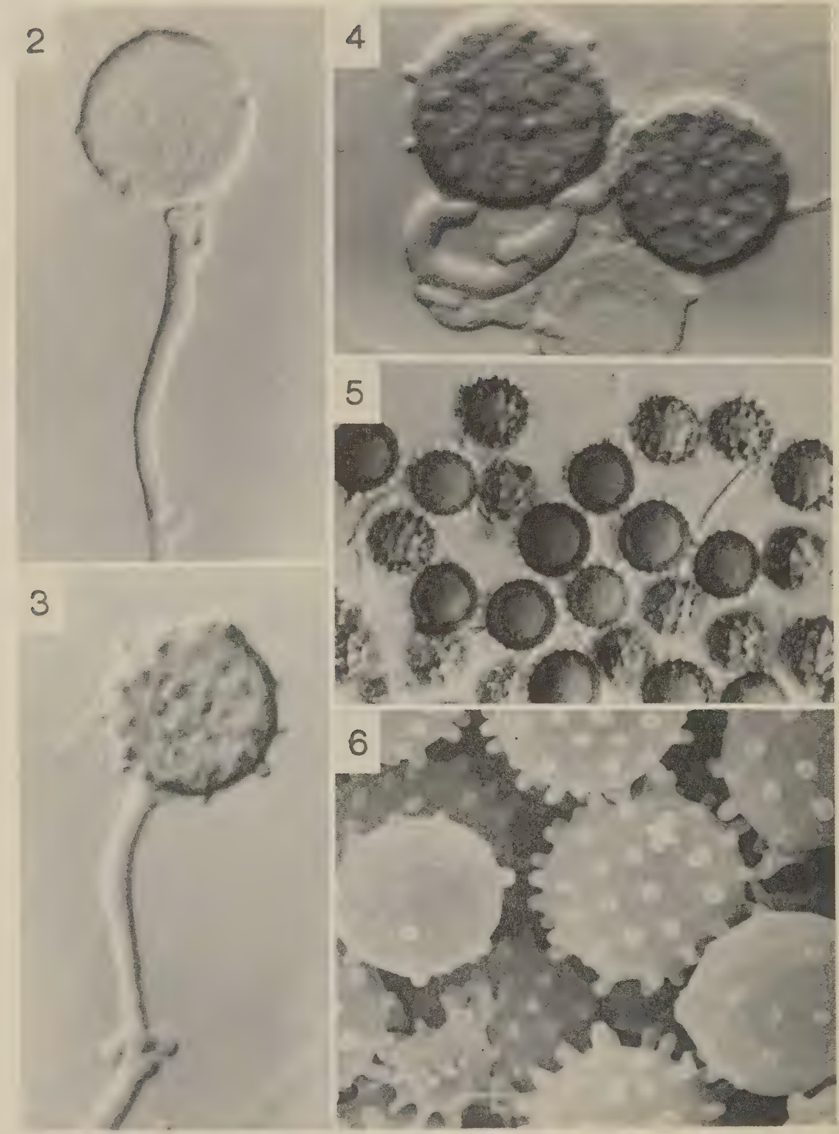
Table 1. Radial growth and conidia formation of *Thermophymatospora fibuligera* strain NHL 2959 at various temperatures

Temperature (°C)	Growth, PDA 4d	Growth, PDA 10d	Conidia, PDA 4d	Conidia, PDA 10d
17	0	1-2		-
20	2-3	15-18	-	-
25	16-17	70-75	-	++
30	46-50	>85	+	+++
35	69-72	>85	++	++++
40	78-80	>85	++	++++
45	13-15	70-73	-	+
50	0	0		

Growth: colony diameter (mm) after 4 and 10 days.
Conidia: ++++, very abundantly produced; +++, abundant; ++, moderate; +, slight; and -, not produced.

Some members of *Myceliophthora* or *Chrysosporium* are macroscopically very similar to this new fungus, differing clearly by the absence of clamp connections at the septa of hyphae and by their association with ascomycetous teleomorphs (van Oorschot, 1980).

The taxonomic position of most thermophilic fungi has been reviewed comprehensively (Cooney and Emerson, 1964; Crisan, 1973; Samson and Tansey, 1977), and reveals that very few basidiomycetous fungi are thermophilic or even thermotolerant. *Coprinus delicatulus* Apinis (considered to be the same as *C. cinereus* (Schaeff. ex Fr.) S. F. Gray) and *Phanerochaete chrysosporium* Burdsall (anam.*Sporotrichum pruinosum* Gilman et Abbott) grow at temperatures over 40°C. From the new fungus the thermotolerant hyphomycete *S. pruinosum* (often noted as *S. pulverulentum* Novobranova or anamorph of *P. chrysosporium*) can be easily distinguished by the white to cream-colored colony, distinctly branched conidiophores, smooth-walled conidia and the absence of



Figs. 2-6. *Thermophymatospora fibuligera*. 2-4. Conidiogenous hyphae with clamp connections and young conidia. ×1300. 5. Matured conidia. ×400. 6. S.E.M. of matured conidia. ×1100.

clamps in its hyphae. Cardinal temperatures for growth of *S. pruinosum* are as follows: minimum 7°C, optimum 36-40°C, and maximum 46-49°C (Stalpers, 1984). Therefore, both fungi exhibit a marked difference in the tolerable limit at the low temperature. *Disporotrichum dimorphosporum* (von Arx) Stalpers (1984), another *Sporotrichum*-like fungus, differs from the new fungus in having dimorphic, smooth-walled, pinkish or hyaline conidia and the occasional presence of multiple clamps in its hyphae. The temperature optimum for growth of *D. dimorphosporum* has been given as 30-32°C and the maximum as 40°C.

Sporotrichum azureum Wright et von Arx (non *S.azureum* Link) is characterized by the formation of hyphae with rounded clamp connections and obovoid to pyriform, smooth or irregularly verrucose conidia (von Arx, 1973). According to Stalpers (1984), *S. azureum* Wright et von Arx is closer to *Ptychogaster* than to the three re-defined members of *Sporotrichum*. Aside from its thermophilism, the unique ornamentation of conidia, which somewhat resembles the wall structure of *Ravenelia spegazziniana* urediniospores (Gardner and Hodges, 1985), serves to distinguish the new fungus from *Ptychogaster* and related genera.

ACKNOWLEDGMENTS

We wish to thank Prof. R.T. Hanlin of the University of Georgia for reviewing the manuscript; and Dr. Y. Otani for correcting the Latin diagnosis.

LITERATURE CITED

Arx, J.A. von. 1973. Further observations on *Sporotrichum* and some similar fungi. Persoonia 7: 127-130.

Cooney, D.G., and R. Emerson. 1964. Thermophilic Fungi, an Account of Their Biology, Activities and Classification. Freeman, San Francisco. 188p.

Crisan, E.V. 1973. Current concepts of thermophilism and the thermophilic fungi. Mycologia 65: 1171-1198.

Gardner, D.E., and C.S. Hodges, Jr. 1985. Spore surface morphology of Hawaiian *Acacia* rust fungi. Mycologia 77: 575-586.

Kornerup, A., and J.H. Wanscher. 1978. Methuen Handbook of Colour. 3rd ed. E. Methuen, London.

Oorschot, C.A.N. van. 1980. A revision of *Chrysosporium* and allied genera. Stud. Mycol. 20: 1-89.

Rayner, R.W. 1970. A Mycological Colour Chart. Commonwealth Mycological Institute, Kew, Surrey & British Mycological Society.

Samson, R.A., and M.R. Tansey. 1977. Guide of thermophilic and thermotolerant fungi. Abstracts, Second International Mycological Congress, Tampa, Florida. 5p.

Stalpers, J.A. 1984. A revision of the genus *Sporotrichum*. Stud. Mycol. 24: 1-105.

MYCOTAXON

Vol. XXVII, pp. 107-111 October-December 1986

GIBBAGO, A NEW PHAEODICTYOCONIDIAL GENUS OF HYPHOMYCETES

Emory G. Simmons

Department of Botany, University of Massachusetts
Amherst, Massachusetts 01003

Gibbago trianthemae Simmons, sp. nov., type of a new genus, is described from parasitized *leaves of Trianthema portulacastrum* L. (Aizoaceae) collected in Cuba, the USA (Texas), and Venezuela. Genus characters are compared with those of somewhat similar genera *Alternaria, Embellisia, Stemphylium, and Ulocladium.*

GIBBAGO Simmons, gen. nov. **Fig. 1**

Etym.: *gibbus* (hump, swelling) + *-ago* (indicating presence of a property), with reference to swollen conidial cells that function as conidiophores.

Conidiophora ex hyphis lateraliter oriunda, solitaria vel 2-4-fasciculata, simplicia vel raro ramosa, recta vel in locis sporiferis geniculata, septata, brunneola. Conidia initio solitaria, ellipsoidea, erostrata, leviter colorata, septis transversalibus longitudinalibusque, cellulis apicalibus tumentibus et conidia secondaria efferentibus. Typus:

Gibbago trianthemae Simmons, *sp. nov. Conidiophora simplicia vel 1-2 geniculate conidiogena, straminea, usque ad 60-80 x 5-6µm. Conidia primigena solitaria, pellucide straminea, laevia, ellipsoidea, demum late ellipsoidea vel late subovate ellipsoidea, vulgo 35-45 x 15-22µm, plerumque 1-4 transverse et 2 longitudine septata, ad mediseptum transversum leniter constricta, poro basali inconspicuo; cellulis apicalis 1-4 tumentibus et conidia secondaria isdem ac conidia primigena efferentibus. Habitatio typi in laesionibus foliorum Trianthemum portulacastrum L. Typus: EGS 21-051, E. G. Simmons, 27-VIII-1967, College Station, TX, USA, lectus; partes in BPI (holotypus) et pro isotypis saltem in IMI et NY conservandae.*

GIBBAGO Simmons, gen. nov. Conidiophores solitary or 2-4 loosely fasciculate, erect, rarely distantly branched, simple with a single apical conidiogenous locus, then often proliferating by means of a secondary conidiophore that arises immediately below the apical cell of the existing conidiophore; septate, slightly pigmented. Conidia initially solitary, ellipsoid, beakless, pigmented, becoming transversely and longitudinally septate; with apical cells swelling slightly and producing secondary conidia similar to initial ones. Type:

Gibbago trianthemae Simmons, sp. nov. Conidiophores simple or 1-2 proliferated, 1-4-transeptate, pale straw-colored, up to 60-80 x 5-6µm, very slightly swollen at apex, producing a solitary conidium at the apex of each proliferation, retaining a distinct umbilicate or crateriform depression at the conidiogenous locus after secession of conidium. Conidia initially solitary, almost perfectly ellipsoid; becoming broadly ellipsoid to broadly subovate-ellipsoid, with 1-4 complete or partial transverse septa (slightly constricted at initial median septum), 2 complete longitudinal septa intersecting at right angles in each conidium half, plus a few shorter ones in transverse sectors of the conidium; clear pale yellow-brown, smooth; with a minute basal pore-scar that is difficult to observe and that lacks any sort of complex surrounding structure or halo of pigmentation; commonly maturing at about 35-45 x 15-22,m; with 1-4 of the apical cells enlarging slightly and each giving rise directly to a single secondary conidium morphologically identical with primary conidia; individual apical (sometimes basal) cells also sometimes giving rise to conidiophores that have the distinctive apically swollen and umbilicate appearance of hyphal conidiophores and that are about 7 x 6µm.

Type EGS 21-051, on well-defined, often extensive lesions in leaves of *Trianthema portulacastrum* L., coll. E. G. Simmons, Texas A. & M. University Experiment Farm, College Station, TX, 27 Aug. 1967; dep. BPI (holotype) and also at least in IMI and NY (isotypes).

All of the nine collections of this fungus known to me are on horse-purslane, a common pantropical weed of cultivated fields. The earliest collection (BPI: Runyon 4480, Sept. 1953) is from Texas, as are a recent isolate contributed by J. K. Mitchell (EGS 38-128) and my own collections (EGS 21-051, 21-052); collections in IMI (coll. R. Urtiaga, 1966-1969) are from Cuba and Venezuela.

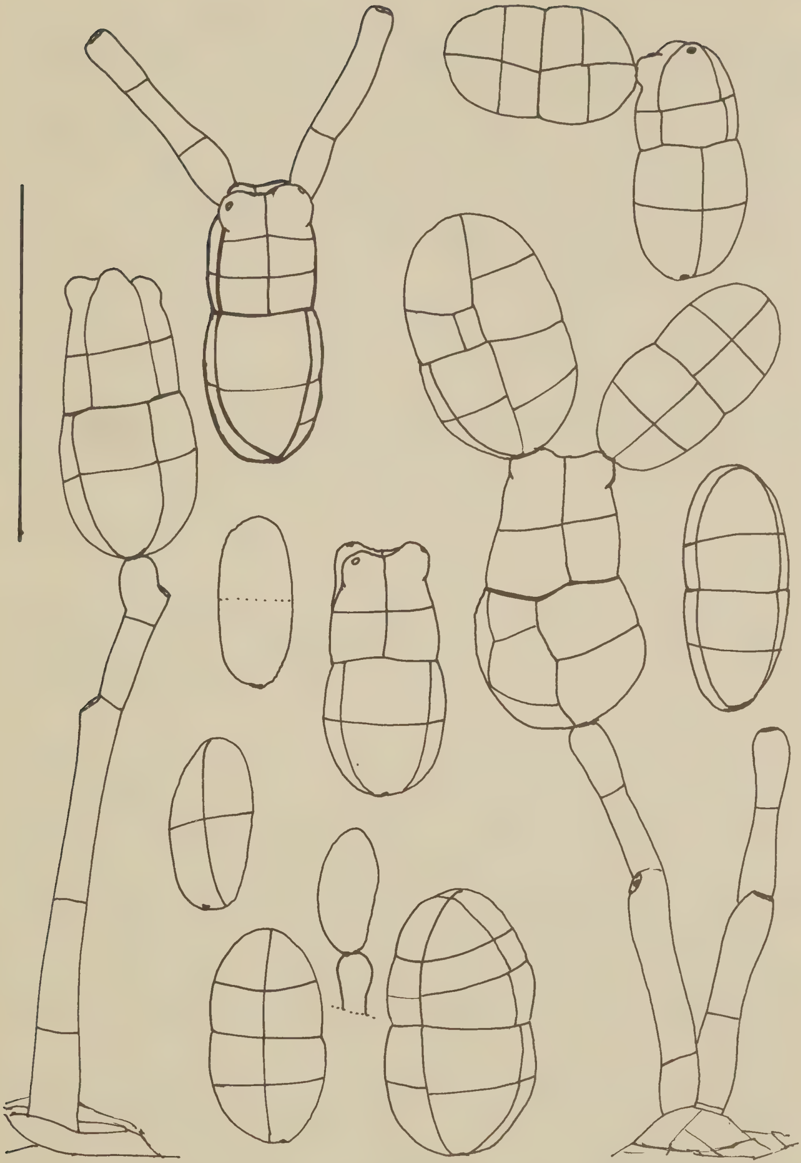


Fig. 1. Gibbago trianthemae, conidia and conidiophores; conidium at upper left exhibits two apical cells that have sporulated directly and two that have produced hyphal conidiophores. Vertical bar = 50µm.

Gibbago trianthemae can be established readily in culture by means of 1-conidium isolates. It grows well and sporulates abundantly in plates of PCA, Hay, and V-8 agars held at moderate temperatures under cycled light (cool-white fluorescent, light/dark, 8/16 hrs). Subsurface mycelial growth is dense and dark on V-8, less so on PCA, and inconspicuous on Hay. Sporulation is excellent at agar surfaces and on the moderate amounts of medium gray, woolly aerial mycelium. Conidia produced in culture are more likely to produce secondary conidiophores and conidia than they are to sporulate precociously directly from their own apical cells. Primary conidiophores produced in culture commonly are 200-300µm long, secondary ones 60-70µm.

Representative 1-conidium isolates ex Type include EGS 21-046 through 21-050; EGS 38-128, received in culture from J. K. Mitchell, is a typical strain. Some of these representatives are being deposited in international culture collections.

Discussion

For many years I have juggled this intriguing fungus among species of several established genera of phaeodictyoconidial Hyphomycetes (*Alternaria*, *Embellisia*, *Stemphylium*, *Ulocladium*), but without enough conviction to publish it as novel in any one of them.

Cfr. *Stemphylium*: *Gibbago trianthemae* conidia, before they proliferate, are stemphylioid in general appearance except that they lack the pigmented halo and the umbilicate depression that usually are conspicuous around the basal detachment scar of *Stemphylium* conidia; conidiophores of the species and their manner of proliferation are not at all those of *Stemphylium*, whose conidiogenous cell characteristically has a subapical pigmented halo and which proliferates by means of a secondary conidiophore that originates in or near the basal septum of a preceding conidiogenous cell and then emerges through the apex of that cell.

Cfr. *Alternaria*: conidia of *G. trianthemae* might be considered erostrate alternarioid, of the sort known for *A. helianthi* and *A. leucanthemi*, but here again the lack of a basal, pigmented halo and conspicuous detachment scar gives pause; conidiophores have the kind of laterally geniculate proliferation characteristic of *Alternaria*.

Cfr. *Ulocladium*: conidia of *G. trianthemae* have some characteristics in common with those of *Ulocladium*, in that the detachment scars of both are very inconspicuous, lack a pigmented halo, and develop on laterally geniculate conidiophores (as in *Alternaria*). However, *G. trianthemae* conidia are not initiated as distinctly obovate, basally pointed juveniles, which are generically typical of *Ulocladium.*

Cfr. *Embellisia*, which is distinguished to a major extent by its species' rigid, wide-band, transverse conidial septa and the semi-collapsing nature of the outer conidial wall, both of which characters are foreign to *Gibbago* as well as to the other genera discussed.

A genus would be established on shaky ground, of course, if it were defined only by such an accumulation of small negative observations. In characterizing *Gibbago,* a unique pattern of secondary sporulation distinguishes the genus from all other phaeodictyoconidial Hyphomycetes with some otherwise similar characters.

Most notably, the rounded distal end of a mature *G. trianthemae* conidium has four cells delimited in part by the right-angle intersection of two longitudinal septa. The apex of each of these cells may become slightly but distinctly enlarged and then, without further change in morphology or pigmentation, produce a secondary conidium; only a minute pore remains at the locus of production after a conidium secedes.

It must be emphasized, in view of the increasingly common use of cultures in identification procedures, that an individual cell in any part of a conidium (but usually in the apex or the base) also may germinate and produce simple conidiophores morphologically indistinguishable, except for origin, from those formed on vegetative hyphae (Fig. 1, upper left). These conidiophores may be short or long (7-70µm), are somewhat swollen terminally, and exhibit an umbilicate apex after release of a conidium. They are germination hyphae converted to a special function; similar ones are produced in most species of the several genera discussed above. However, except for the act of conidium production, they have no resemblance to the directly sporulating cells of *Gibbago trianthemae* conidia, which are held to be typical of the genus.

* * * * * * *

Margaret E. Barr Bigelow continues to be the subject of my thanks for her prepublication editorial vetting of this manuscript.

MYCOTAXON

Vol. XXVII, pp. 113-117 October-December 1986

A NEW SPECIES OF THE LICHEN GENUS SULCARIA (ASCOMYCOTINA, ALECTORIACEAE) FROM CALIFORNIA

IRWIN M. BRODO

National Museums of Canada, Museum of Natural Sciences,
Ottawa, Ontario K1A 0M8, Canada.

SUMMARY

A puzzling alectorioid lichen was discovered in southern California that seems best classified as a Sulcaria. It is caespitose, abundantly isidiate, and contains protocetraric acid. It is named here as a new species: Sulcaria isidiifera Brodo.

Halfway between San Franscico and Los Angeles, in Los Osos Oaks State Reserve, a very odd alectorioid lichen was collected that is remarkable with respect to chemistry and morphology. Although sought in numerous nearby areas in California by the original collectors, Charis Bratt and Mason Hale, the lichen is so far known only from this one forest. The locality is a very special one, with ancient (600-800 year old) trunks of Quercus agrifolia forming a climax community over stabilized sand dunes originally covered by scrub and chaparral (Wieman 1980). It is also the type locality of the recently described Hypogymnia mollis Hale, a species possibly related to a Moroccan taxon (Pike & Hale 1982).

This lichen proved extremely difficult to classify as to genus. The genus Alectoria in the broad sense was recognized to be assemblage of closely related genera by Brodo & Hawksworth (1977), including Alectoria s. str., Bryoria and Sulcaria, distinguished by a combination of chemical, anatomical, and especially spore characteristics. This new species, immediately distinctive by virtue of its longitudinally split, abundantly isidiate-sorediate branches, and its production of protocetraric acid, is unfortunately without apothecia. Spore characters, which would immediately serve to classify the species (2-4 brown, simple spores per ascus in Alectoria; 8 colorless, simple spores in Bryoria; (6-)8 colorless, 1(-3) septate spores in Sulcaria), were therefore unavailable. Repeated attempts by Bratt and Hale to find thalli with fruiting bodies proved unsuccessful.

The branches of the new lichen are split longitudinally as they are in species of *Sulcaria*. The branches are not hollow as in *S. sulcata*[1], however, but are packed with hyphae. In fact, the "sulci" are filled with soredia from which clusters of short or long spinulose isidia develop (Fig. 3). (The branches of *S. virens* and *S. badia*, however, are not hollow either.)

The production of protocetraric acid and (in one specimen) a trace of what appears to be virensic acid, links the species best with *Sulcaria*, where known species produce psoromic or virensic acid, or atranorin. A chemical parallel can be found in the *Lecanora caesiorubella* group, where these four compounds occur in closely related species. *Bryoria* is also characterized by the production of *beta*-orcinol depsidones, whereas no species of *Alectoria* has these compounds. Although traces of protocetraric acid occur in species of *Bryoria* containing fumarprotocetraric acid as a principal constituent, this substance has not been found as the main product in any known *Bryoria*.

Anatomically, the new species most resembles an *Alectoria* (with thick, knobby medullary hyphae and decomposed cortical surface), or a *Bryoria* sect. *Implexae* (its cortical hyphae having very little strengthening matrix), but the cortical structure of *Sulcaria badia* and *S. virens* is somewhat similar.

With respect to color, our material is closest to *Sulcaria* and a few species of *Bryoria* sect. *Implexae* (such as *B. spiralifera* or *B. kuemmerleana*). No species of *Alectoria* has the same badious tint.

The isidiate soralia seen in the new species are rather unique in the Alectoriaceae. They develop from a gradual disintegration of the cortex rather than from a fissuring as in *Bryoria furcellata* or *B. smithii*, or a proliferation from a raised pseudocyphellum as in *Alectoria imshaugii*. Viewing the various developmental stages of sulca formation temporally, one can describe the situation as follows: At first, a few short isidia grow superficially on a branch. The cortex under and around the isidia is rough and is obviously deteriorating. The isidia develop along a "line" running down the branch. The cortex finally disintegrates along this line, which becomes transformed into a sorediate sulca filled with spinulose isidia of various lengths. Sometimes the sulcae are moderately deep, but most are simply wide and packed with granulose soredia and isidia. The proposed name of the new species is based on these unusual structures.

It would seem that the new species is closely allied to either or both *Sulcaria badia* and *Bryoria spiralifera*.

---

[1] Nomenclature follows Brodo & Hawksworth (1977).

Material of the latter species found in the Los Osos Oaks State Reserve occasionally produces an incipient sulca instead of a spiralled pseudocyphellum bringing it closer to *Sulcaria* morphologically. In view of the fact that all of these species are invariably sterile, I can see no point in speculating on more appropriate generic designations at the moment. It does, however, make me more inclined to classify the new species as a *Sulcaria*.

Sulcaria isidiifera Brodo, sp. nov. Figs. 1-3

Thallus caespitosus, cremens vel pallissime brunneus vel badius, opacus; rami principales iso-dichotomiter vel aniso-dichomiter fastigiati, ramis lateralibus spinulosis plus minusve perpendicularibus, sulcati, sulcis isidio-sorediatis spinuliferibusque. Apothecia et pycnidia non vidi. Thallus acidum protocetraricum continens.

Typus: U.S.A., California, San Luis Obispo County: Los Osos Oaks State Reserve, Los Osos Valley Road, alt. 100 ft., in *Adenstoma fasciculatum*. *Bratt 3871*, et *J. Larson*, 8 Jan. 1984 (holotypus: CANL; isotypi: US, hb. BRATT).

Thallus dull yellowish-white (92[2]) grading into light brown (57) and reddish brown (42) at the more exposed tips; rarely shades of olive-grey (112) in places (perhaps ecologically influenced); caespitose, 3-5 cm long; main branching isotomic to anisotomic dichotomous, with more or less perpendicular spinulose branches developing from splits in the thallus; branches splitting lengthwise and opening into rather wide, linear soralia filled with spinulose isidia and spinules, often with brown tips; main branches 0.3-0.5 mm wide; secondary branches 0.15-0.3 mm wide; branches fairly even and smooth except for the sulci and isidial development; branches very brittle; pseudocyphellae apparently absent, or developing immediately into isidiate soralia. Apothecia and pycnidia not seen.

Cortex KOH-, C-, KC- or faint pink, PD+ orange; medulla KOH-, C-, KC-, PD-or faint orange. Contains protocetraric acid, rarely with an unidentified compound (R_F classes 3, 5-6, 5: Culberson 1972) and a trace of (?)virensic acid as accessory substances.

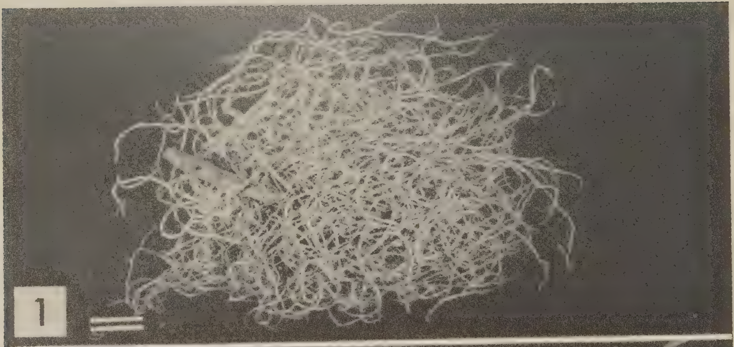
Habitat: On branches of *Quercus agrifolia*, *Adenostoma fasciculatum*, and *Coenothus ramulosus* in sandy areas.

Distribution: Known only from the type locality.

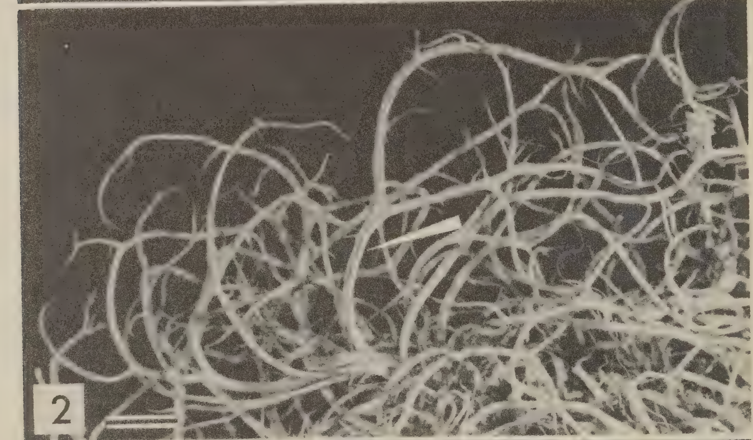
Specimens seen: U.S.A. California. San Luis Obispo County: Los Osos Oaks State Reserve, *Bratt 3871* (type), *3851B*, *4029*, *3859* (hb. BRATT, CANL); *Hale 57816* (CANL, US)

---

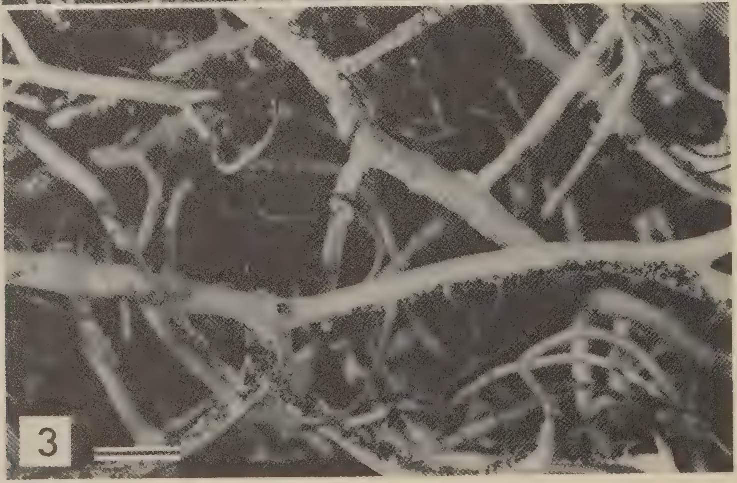
[2] Numbers following colors refer to Kelly (1965).



1



2



3

ACKNOWLEDGEMENTS

I am indebted to Charis Bratt and Mason Hale in bringing this interesting taxon to my attention, and for trying so persistently to find fertile material. I also thank Dr. Hale for revising the latin description, and David Hawksworth for his views on the problem.

LITERATURE CITED

Brodo, I.M. & D.L.Hawksworth. 1977. Alectoria and allied genera in North America. Opera Botanica 42: 1-164.

Culberson, C.F. 1972. Improved conditions and new data for the identification of lichen products by a standardized thin-layer chromatography method. Journal of Chromatography 72: 113-125.

Kelly, K.L. 1965. ISCC-NBS color name charts illustrated with centroid colors. -Supplement to national Bureau of Standards Circular 553. Washington, D.C.

Pike, L.H. & M.E. Hale, Jr. 1982. Three new species of Hypogymnia from western North America (Lichenes: Hypogymniaceae). Mycotaxon 16: 157-161.

Wieman, H. 1980. Nature walks on the San Luis coast. Padre Publications, San Luis Obispo, California.

Figures 1-3. Sulcaria isidiifera, holotype (Bratt 3871). -1. A single thallus. Scale = 5 mm. -2. Branches, showing shallow sulci (arrow). Scale = 2 mm. -3. Close-up of isidiate soralia and spinules. Scale = 1 mm.

MYCOTAXON

Vool. XXVII, pp. 119-125 October-December 1986

BADARISAMA SOJAE, A NEW BULBIL-FORMING GENUS AND SPECIES

I. K. KUNWAR[1], J. B. MANANDHAR[2], and J. B. SINCLAIR
Department of Plant Pathology, University of Illinois at
Urbana-Champaign, 1102 S. Goodwin Avenue, Urbana, IL 61801

Abstract

A hitherto undescribed bulbil-producing fungus, _Badarisama sojae_ gen. et sp. nov. is described. It has been observed frequently growing with _Alternaria alternata_ from surface-sterilized soybean (_Glycine max_) seeds on potato-dextrose agar plates (25°C). Its colonies produce pseudoparenchymatous, raspberry-like, black bulbils. No other method of sporulation is known.

Introduction

A bulbil-producing fungus has been encountered growing in association with _Alternaria alternata_ (Fr.) Kiessler on soybean (_Glycine max_ (L.) Merr.) seeds (10). Weresub & LeClair (11) used the term 'bulbils' for papulospore-like structures made up of pseudoparenchymatous tissue. Papulospores were described by them as "thallodic propagules differentiated almost from the inception into central and sheathing cells". The term 'spore-knaueln' used by Eidam (2) for the papulospores of _Papulasporea parasiticum_ (Karsten) Harz was based on a definition by Dodge (1). Fungi producing bulbils rather than true papulospores, which had previously been included in _Papulaspora_ Pruess by Hotson (6,7), were removed by Weresub & LeClair (11) to other genera. Bulbils have been recognized only in the basidiomycetous genera _Burgoa_ Goid. and _Minimedusa_ Weresub & LeClair (5). Our bulbil-producing fungus differs from these genera.

Materials and methods

During 1984, symptomatic soybean seeds were selected at random and surface sterilized for 5 min with 0.5% NaOCl (10% Clorox) and then washed in two changes of sterilized, deionized distilled water. The seeds were plated on 9-cm culture plates containing potato-dextrose agar (Difco) acidified (pH 4.5) with lactic acid (APDA) and incubated under 12-hr photoperiods of cool fluorescent light (800 uEin/m^2/sec) for 5 da at 25°C. We frequently observed and isolated a bulbil-producing fungus consistently associated with colonies of _A. alternata_.

---

[1] Present address: % A. C. Kunwar, Raman Research Institute, Bangalore 560080, India

[2] Present address: Division of Plant Pathology, Department of Agriculture, Lalitpur, Nepal.

To assist in the identification, in selecting a suitable medium for growth, and to try to induce reproductive structures other than bulbils, the fungus was cultured on the following media and incubated in the 12-hr photoperiod described previously or in continuous dark or continuous light: 3.5% Czapek-dox agar, 2.3% lima bean agar, 3.5% malt-extract agar, 7.3% oat-meal agar (OMA), nonacidified PDA, vegetable-juice agar, and 2% water agar, each with or without two to three autoclaved-sterile, 5-cm alfalfa (*Medicago sativa* L.) or soybean stem pieces per plate, or halved soybean seeds, or green pods (four to five pieces/plate) added aseptically. To confirm that it was not a sclerotium-forming *Alternaria* (3), individual bulbils and single conidia of *A. alternata* were subcultured repeatedly on APDA and OMA and studied under a binocular bright-field microscope. Living cultures were compared with those of *Burgoa verzuoliana* Goid. (ATCC-24040) and *Papulospora pannosa* Hotson (ATCC-24406).

A. alternata and the bulbil-forming fungus were studied in dual cultures. Five-mm discs were cut from the edge of pure cultures of colonies of either fungus and both fungi placed adjacent to one another at the center of each of four 9-cm APDA culture plates and incubated under light as described previously. Culture plates with either fungus alone served as controls.

Culture filtrates of *A. alternata*, from cultures grown on 2.4% potato-dextrose broth for 2 wk at 25°C, were filtered through 0.2 µm pore Nalgene filters, and mixed with PDA (1: 20 v/v), and used to determine any effect on the growth of the bulbil-forming fungus. Five-um discs were cut from the edge of PDA colonies of the latter and placed in the center of 9-cm culture plates amended with the culture filtrate of *A. alternata*. Cultures grown on nonamended PDA served as controls. Growth rate was recorded after 7 da at 25°C.

Taxonomic part

Our observations indicate that the bulbil-forming fungus and *A. alternata* are discrete and unrelated taxa. Since the former appears to be unique in its morphology, it is herein described as new.

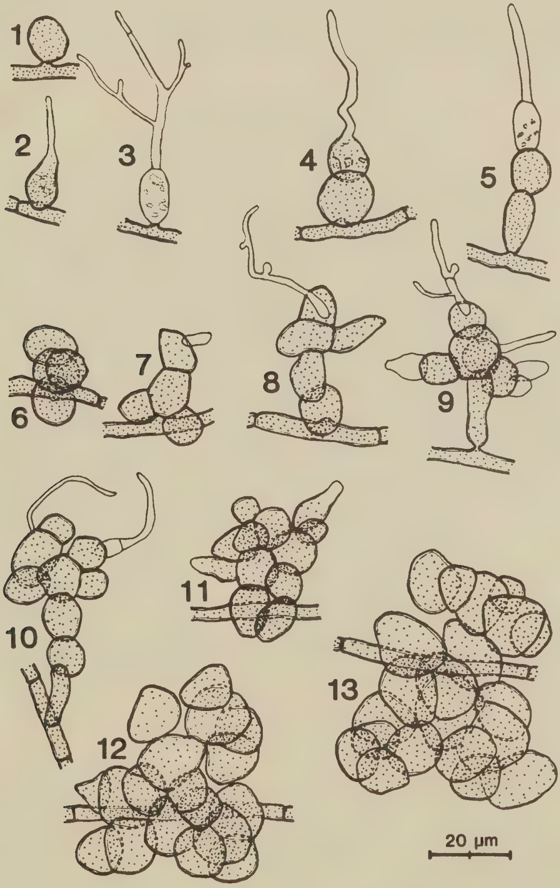
Badarisama Kunwar, Manandhar et Sinclair. (Figs. 1-20)
(etym. Sanskrit - badari - berry, sama = like

Coloniae in agaro cum farina avenacea (OMA) vel cum dextroso et tuberibus *Solani tuberosi* (PDA) composito satae immersae vel aliquid superficiales, effusae, fuscae; mycelium ex hyphis ramosis, septatis, subhyalinis, zygodesmatibus carentibus, maturis fusco-brunneis, compositum; bulbuli blastici, e cellula vel hypha laterali ad angulum rectum ab axe principali orti; bulbulorum cellulae crasse tunicatae, pseudoparenchymaticae, homogeneae, brunneae, granulares, e textura globosa in texturam angularem desinentes; bulbuli instar fructuum Rubi, globosi vel subglobosi vel enormes, maturi fusci. Species typica: *B. sojae*.

Colonies on OMA and PDA immersed to somewhat superficial, effuse, dark; mycelium composed of branched, septate, subhyaline hyphae lacking clamp connections, becoming dark brown at maturity; bulbils blastic; arising laterally at right angles to the main axis from a single lateral cell or hyphae; cells of bulbils thick-walled, pseudoparenchymatous; homogeneous, brown granular, composed of textura globulosa to textura angularis; bulbils raspberry-like, globose to subglobose or irregular, dark at maturity.

B. sojae Kunwar, Manandhar et Sinclair. (Figs. 1 to 20)

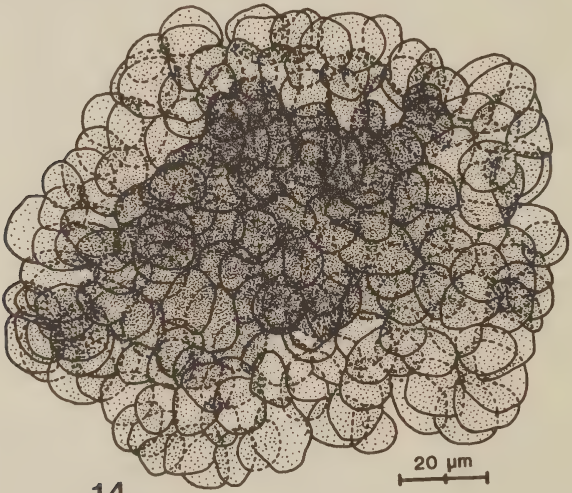
Coloniae in OMA satae 4.5-6 cm, in PDA usque ad 1.0 cm diametro, in spatio septem dierum sub calore 25°C, atrae; mycelium exiguum, procumbens, per vel super substratum



Figures 1-13. Badarisama sojae: Successive stages in the development of a bulbil.

crescens, hypharum cellulis multinucleatis, axe prinicipali bulbilifero 4.2-7.2 um crasso; cellulae vel hyphae laterales bulbiliferae 6.8-16.0 um crassae; bulbuli plerumque in agaro immersi, fumosi, maturitate atri, forma magnitudineque enormes, 91.0-218.4 x 136.0-236.6 um, medio 150.9 x 171.8 um, cellulis 9.0-18.5 x 16.4-22.5 um, medio 15.5 x 17.6 um.

Colony diam 4.5 to 6.0 cm on OMA and up to 1 cm on PDA in 7 da at 25°C, black; mycelium scanty, procumbent, growing on or in the substratum, hyphal cells multinucleate, bulbiliferous main axis hyphae 4.2 to 7.2 um in width; bulbiliferous lateral cells or hyphae 6.8 to 16 um in width; bulbils mostly immersed in the agar, smoke-colored, becoming black at maturity, variable in shape and outline, ranging from 91.0 to 218.4 x 136.6 um, average size 150.9 x 171.8 um, cells in the bulbil ranging from 9.1 to 18.5 x 16.4 to 22.5 um, average size of 15.5 x 17.6 um.

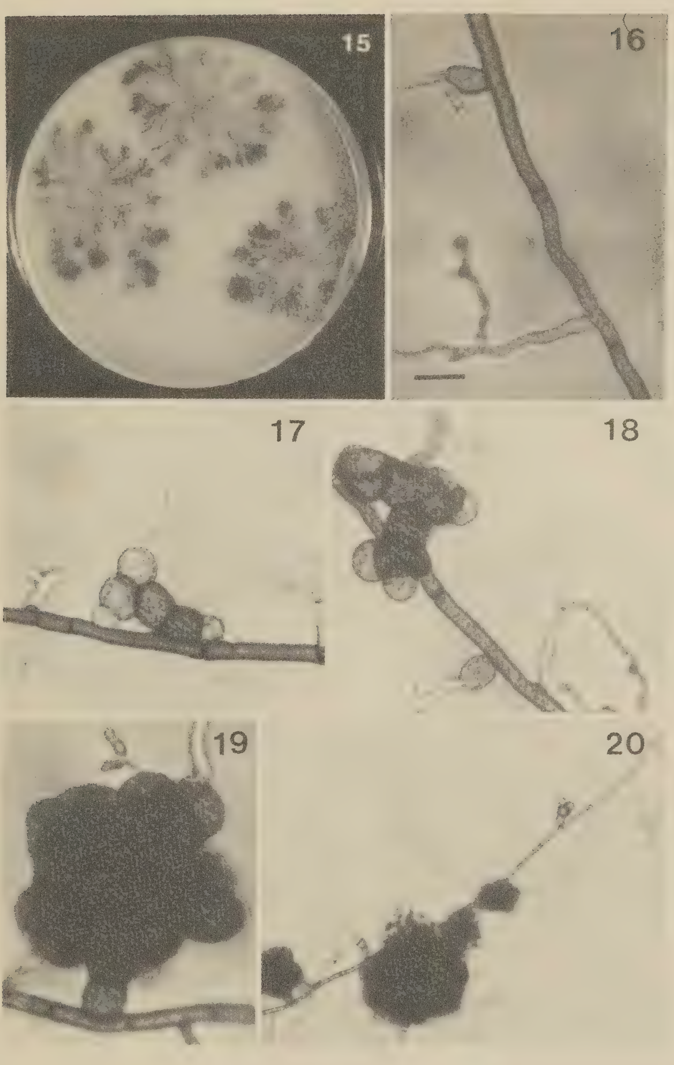


14

Figure 14. Badarisama sojae: A mature bulbil

Isolates examined: from soybean seed, Agronomy-Plant Pathology South Farm, Univ. of Illinois at Urbana-Champaign Urbana, IL, October 1984, I. K. Kunwar, ILLS-45312, holotype: and a living culture in the American Type Culture Collection (ATCC-60345).

The colony diam of *B. sojae* was up to 1.5 cm in 7 da on media other than OMA including APDA. When grown in dual culture on APDA with *A. alternata*, colony diam was 6 to 7 cm, but 1 cm in the control. Mycoparasitism was not observed. When grown in PDA amended with a culture filtrate of *A. alternata*, the rate of growth of *B. sojae* was 2 to 3.5 cm. It appears that *A. alternata* produces a factor or factors that stimulates faster and denser growth of *B. sojae* in culture.



Figures 15 to 20. *Badarisama*: 15. 7-da-old colony on oat-meal agar, scale = 1.4 cm; 16 to 19. Photomicrographs of stages in the development of a bulbil, scale = 15 um; and 20. Photomicrograph of developing and a mature bulbil on a hypha under bright-field microscope, scale = 62 um.

The mycelium was subhyaline, becoming thick-walled and dark brown in 3 to 4 da. Subhyaline hyphal cells contained indefinite numbers of oil globules (Figs. 3-5, 16-18). Septa were formed with a refractive thickened peripheral ring. Anastomosis of hyphae was common. Clamp connections were not observed.

Bulbils formed along the hyphae, blastic, developing laterally from parts of the basal cell (Figs. 1-10, 16-18). Cells within the bulbils develop successively in the same manner from older mature cells. In a few cases, bulbils give rise to hyaline hyphae (Figs. 1-5, 7-11). Chains of bulbils are formed in 2- to 3-mo-old cultures (Figs. 14, 19, 20).

Discussion

Since B. sojae reproduces only by bulbils, we placed it in the Form-Order Agonomycetales (9). In Burgoa, cells in a bulbil expand synchronously into individual bubbles. In Minimedusa, bulbil primordia appear as a group of lateral aerial hyphal branches converging to form a globose bulbil. The dark bulbils of Badarisama can resemble either the dark papulospores of Papulaspora atra Hotson and P. pannosa, or dark bulbils of Burgoa nigra (Hotson) Goid. However,the papulospore primordia of P. atra are formed from a group of terminal cells on lateral branches (8), and mostly intercalary in P. pannosa (6,7). The bulbils of B. nigra are formed by the synchronous expansion of bulbil cells (4). The bulbil/papulospore primordia and successive development of B. versuoliana (ATCC-24040) and P. pannosa (ATCC-24406) were different from Badarisama sojae. Therefore, Badarisama is different from the bulbiliferous genera Burgoa and Minimedusa by the presence of procumbent, immersed hyphae; homogeneous, nonsynchronous and pseudoparenchymatous bulbils formed from individual lateral cells or hyphae acting as primordia; and the absence of clamp connections.

Acknowledgements

The authors wish to thank J. L. Crane, D. A. Glawe, Univ. of Illinois at Urbana-Champaign (UIUC), Urbana, IL for their valuable suggestions and advice, assisting in the naming of the fungus, and for critical manuscript review; to D. P. Rogers, Professor Emeritus, UIUC, for Latin diagnosis; and G. Morgan-Jones, Auburn Univ., Auburn, AL for critical review of the manuscript.

Literature cited

1. Dodge, B. O. 1920. The life history of Ascobolus mangificus. Origin of the ascocarp from two strains. Mycologia 12:115-134.
2. Eidam, E. 1883. Zur kenntniss der Entwicklung bei den Ascomyceten. In Beitrage zur Biologie de Pflanzen. F. Cohn (ed.) 3:377-433.
3. Ellis, M. B. 1976. More Dematiaceous Hyphomycetes. Commonw. Mycol. Inst. 507pp.
4. Goidanich, G. 1938. Studie sulla microflora fungina cella pasta di legno destinata alla fabbricazione cella carta (Part I). Boll. Sta. Patol. Veg., Roma,N.S. 17:305-399.
5. Hawksworth, D. L., Sutton, B. C., & Ainsworth, G. C. 1983. Ainsworth and Bisby's Dictionary of the Fungi. 7th ed. Commonw. Mycol. Inst., Kew, Surrey, England.

6. Hotson, H. W. 1912. Culture studies of fungi producing bulbils and similar propagative bodies. Proc. Amer. Acad. Arts & Sci.48:277-306.
7. Hotson, H. W. 1917. Notes on bulbiliferous fungi with a key to described species. Bot. Gaz. 64:265-284.
8. Hotson, H. W. 1929. *Papulospora atra* n. sp. Amer. J. Bot. 16:219-220.
9. Kendrick, W. B. & Camichael, J. B. 1973. Hyphomycetes. p. 323-509. In The Fungi. Vol. IVA. G. C. Ainsworth, F. K. Sparrow & A. S. Sussman (eds.). Academic Press, Inc., New York, NY.
10. Kunwar, I. K., Manandhar, J. B., & Sinclair, J. B. 1986. Histopathology of soybean seeds infected with *Alternaria alternata*. Phytopathology 76: in press.
11. Weresub, L. K., & LeClair, P. M. 1971. On *Papulaspora* and bulbilliferous basidiomycetes *Burgoa* and *Minimedusa*. Can. J. Bot. 49:2203-2213.

MYCOTAXON

Vol. XXVII, pp. 127-145 October-December 1986

NOTES DE NOMENCLATURE CONCERNANT LES HYMÉNOMYCÈTES; IV
SUR QUELQUES ÉPITHÈTES SPÉCIFIQUES PRÉOCCUPÉS. 3.

Régis COURTECUISSE
33, rue de Piètre
F. 59249 - AUBERS

KEY-WORDS : Hymenomycetes, *Entoloma*, nomenclature, type studies.

ABSTRACT : Some new cases of preoccupied epithets are studied. The following new names are proposed: *Entoloma subaeruginosum, E.egonii, E.largentii, E.flavoides, E.guzmanii.* Some new combinations are added: *E.virescens* (Berk. and Curt.), *E.largentii var. badiodorsum* (Largent), *E.largentii var. alnicola* (Largent), *E.largentii var. farinaceum* (Largent).

RESUME : Quelques nouveaux cas d'épithètes préoccupés sont étudiés. Les nouveaux noms suivants sont proposés: *Entoloma subaeruginosum, E. egonii, E.largentii, E. flavoides, E. guzmanii.* Quelques nouvelles combinaisons sont ajoutées: *E.virescens* (Berk. and Curt.), *E.largentii var. badiodorsum* (Largent), *E.largentii var. alnicola* (Largent), *E.largentii var. farinaceum* (Largent).

INTRODUCTION :

Cette note fait suite au travail publié précédemment (COURTECUISSE, 1984), et prend en considération quelques épithètes préoccupés et quelques problèmes de nomenclature dans le genre *Entoloma* (Fr.) Kummer. Des études de type sont proposées pour étayer les remaniements nomenclaturaux.

REMERCIEMENTS :

Nous tenons à remercier très sincèrement les directeurs des herbiers et muséums suivants, qui nous ont aimablement accordé le prêt des types et espèces étudiés: ENCB, FLAS, HSC, NY, NYS, TMI; de même que les collègues qui, à des titres divers nous ont permis la réalisation de ce travail: M.Bon (Saint-Valery-sur-Somme), J.Géhu-Franck (Lille), G.Guzman (Xalapa- Mexique), J.W. Kimbrough (Gainesville- USA), T.Kuyper (Leiden- Hollande), D.L.Largent (Arcata- USA), E.Nagasawa (Tottori- Japon), M.E.Noordeloos (Leiden- Hollande), C.T. Rogerson (Bronx- USA), J.Trimbach (Nice) et C.VanHaluwyn (Lille).

ENUMERATION ALPHABETIQUE DES EPITHETES CONSIDERES :

1. AERUGINOSUM

a. *Leptonia aeruginosa* Peck 1889 *Bull.Torr.Bot.Cl.* 26:65

Cette espèce est étudiée par HESLER (1963:327) et par LARGENT (1977: 162). Elle se place dans la section des *Viridicaules* Largent 1974, appartenant au sous-genre *Leptonia* (Fr.)Noordeloos, section *Paludocybe* (Largent)Noordeloos et semble bien individualisée au vu des descriptions publiées par ces deux auteurs.

Nous avons examiné le type de ce taxon (NYS) et nos observations correspondent à celles de HESLER et de LARGENT. Nous donnons simplement un dessin des spores de cet exemplaire type (Fig.1).

Une combinaison dans le genre *Entoloma* (Fr.)Kummer est impossible en raison de l'existence de l'*Entoloma aeruginosum* Hiroe (voir ci-dessous). Un nouveau nom est donc nécessaire. Nous proposons:

Entoloma subaeruginosum Courtecuisse *nom.nov.*
= *Leptonia aeruginosa* Peck 1889 *Bull.Torr.Bot.Cl.* 26:65
= *Leptoniella aeruginosa* (Peck)Murrill 1917 *N.am.Fl.* 10:89
non *Entoloma aeruginosum* Hiroe 1939 *Appl.Mushr.Sci.* 4:1

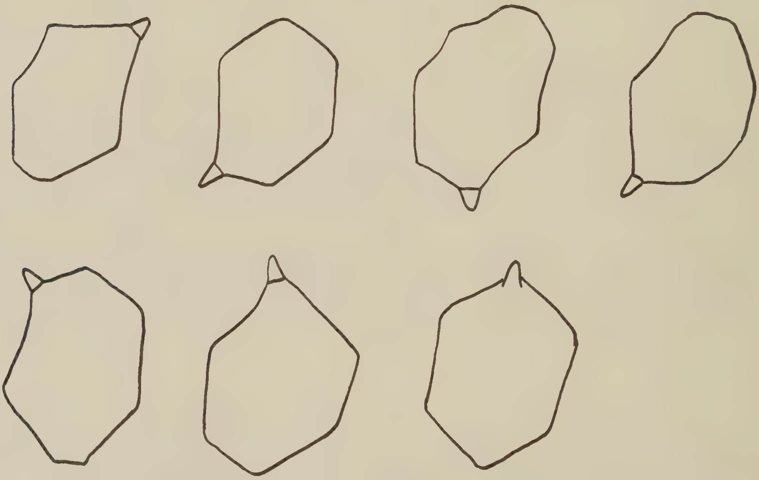


Fig.1 - *Entoloma subaeruginosum* Court. (*Leptonia aeruginosa* Peck - Type NYS) Spores

b. *Entoloma aeruginosum* Hiroe 1939 *Appl.Mushr.Sci.* 4:1

Cette espèce a été assez abondamment étudiée, de même que son groupe, principalement par HORAK (1971, 1973, 1978, 1980). Une synonymie très importante existe, et nous la reproduisons ci-dessous, non sans en discuter préalablement quelques points particuliers.

Le binôme le plus ancien correspondant à ce taxon semble être *Agaricus virescens* Berk. et Curt. 1860. HORAK (1976:200) a combiné ce binôme dans le genre *Entoloma* en citant un basionyme incomplet et imprécis. Nous pensons utile de valider ci-dessous cette combinaison.

Nous avons examiné le type de *Agaricus virescens* Berk. et Curt. (K872). Celui-ci est en assez mauvais état, en particulier sur le plan microscopique et seules les spores peuvent être observées de façon convenable.

Agaricus virescens Berk. et Curt.; Type K.872; Bonin Isles; Herb.Mycol.Berk. 1879.

Spores de forme cubique, X 8,8-11 µ. (Fig.2)

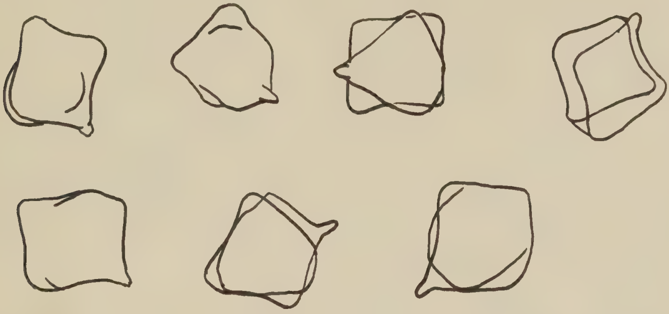


Fig.2 - *Entoloma virescens* (B.et C.)Horak *c.n.* (*Agaricus virescens* B.et C. - Type K) Spores.

Il nous semble très regrettable que les autres particularités anatomiques de ce champignon ne puissent être observées. En effet, nous avons obtenu le prêt de deux récoltes de *Entoloma aeruginosum* Hiroe, synonyme d'*Ag.virescens* d'après HORAK, grâce à l'obligeance de E. NAGASAWA (le type en aurait été perdu d'après le Dr. HIROE), et quelques détails nous semblent différer des observations que nous avons faites sur *Ag.virescens* d'une part, et des descriptions données par ROMAGNESI pour son *Rhodophyllus holocyaneus* d'autre part, autre espèce placée en synonymie de *Ag.virescens* par HORAK.

Donnons tout d'abord une description des spécimens de *E.aeruginosum* Hiroe.

Entoloma aeruginosum Hiroe; TMI 1945; On soil in mixed wood; Ochidani, Tottori City; Sept.19, 1974; E.Nagasawa.

Exsiccatum de teinte vert foncé.

Spores X 9,5-11,5-(12) µ (+apicule), de forme cuboïde complexe, prenant des allures d'étoile à 6 branches selon l'orientation, avec les faces convexes, séparées par des angles assez nets. (Fig.3)

Basides 4-sporiques, de grande taille, bouclées.

Sous-hyménium coralloïde complexe.

Trame subparallèle.

Boucles présentes, fréquentes.

Cheilocystides nombreuses (Fig.4); Pleurocystides nombreuses, semblables aux cheilocystides, mais plus petites. (Fig.5)

Pigment granuleux, rose-orange dans le sous-hyménium, mais verdâtre dans la trame et les cystides. Les granules présents dans la trame sont plus volumineux que ceux des cystides (observations dans le Rouge Congo ammoniacal).

Rhodophyllus aeruginosus (Hiroe)Hongo; TMI 4300; on soil in mixed wood; Kokoge, Tottori City; 25.09.76; T.Arida.

Spores X 10-12-(12,5) µ (+apicule), cuboïdes à contour plus ou moins arrondi, de forme très complexe, très difficile à dessiner ! (Fig.6).

Basides 4-sporiques, de grande taille, 50-60 X 10-15µ(+ stérigmates), bouclées.

Sous-hyménium plus ou moins coralloïde.

Trame subparallèle.

Boucles fréquentes.

Cheilocystides (Fig.7) et pleurocystides (Fig.8) présentes, 45-60 X 3,5-10 µ.

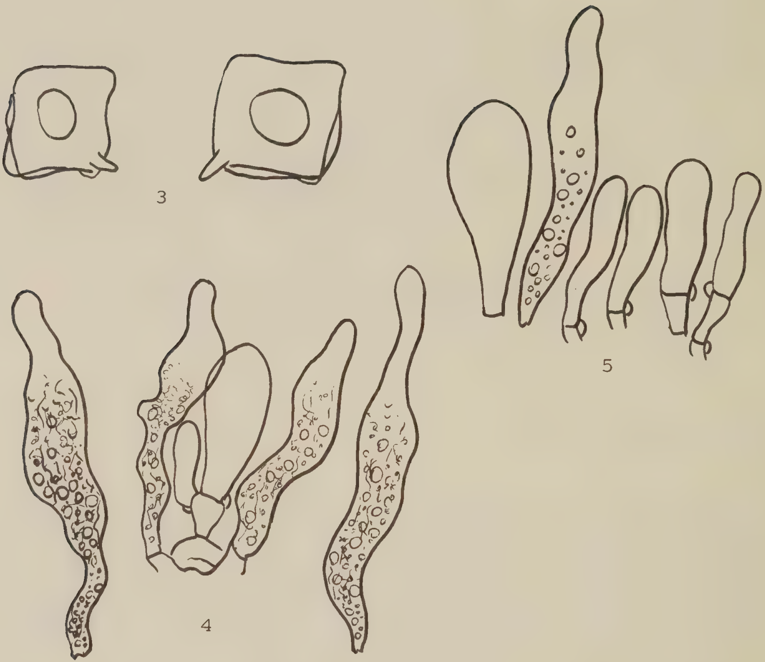


Fig. 3-5 - *Entoloma aeruginosum* Hiroe (TMI 1945); 3: Spores; 4: Cheilocystides 5: Pleurocystides et basidioles.

Hyphes remarquablement colorées par un pigment intracellulaire granuleux vert-jaune vif (pouvant évoquer des algues !), plus ou moins brunâtre vers le sous-hyménium. Cellules faciales à pigment identique, mais plus brun.

Il nous a semblé frappant que les spores de *Agaricus virescens* Berk. et Curt. soient très nettement cubiques et ne posent aucun problème au dessin, alors que celles de *Entoloma aeruginosum* Hiroe sont de forme très complexe, bien que bâties sur le modèle cubique, et causent de véritables difficultés au dessinateur.

C'est pour cette raison en particulier qu'il serait très intéressant de pouvoir controler les autres caractères microscopiques d'*Agaricus virescens*.

D'autre part, HORAK (1980) synonymise également *Rhodophyllus holocyaneus* Romagnesi 1941 à *A.virescens* (donc à *E.aeruginosum*). Or, ROMAGNESI, dans sa description princeps, insiste sur l'existence "dans le sous-hyménium... d'une couche très distincte d'hyphes grêles brun-noirâtre dans l'ammoniaque et vert-noir dans l'acide sulphurique, sans corpuscules très différenciés, tranchant nettement sur le médiostrate."

Cette couche nette n'a pas pu être retrouvée sur les exemplaires japonais de *E.aeruginosum*, provenant d'une localité citée par Hiroe dans sa publication originale et dont l'identité ne peut être mise en doute. Il est vrai que sur ces spécimens, la coloration verte de la trame passe au brun-vert et au brun vers le sous-hyménium, mais ce passage se fait d'une façon assez progressive et ne forme pas de séparation bien tranchée.

Il semble donc que la correspondance entre *Agaricus virescens* et *Entoloma aeruginosum* d'une part, et ce dernier et *Rhodophyllus holocyaneus* d'au-

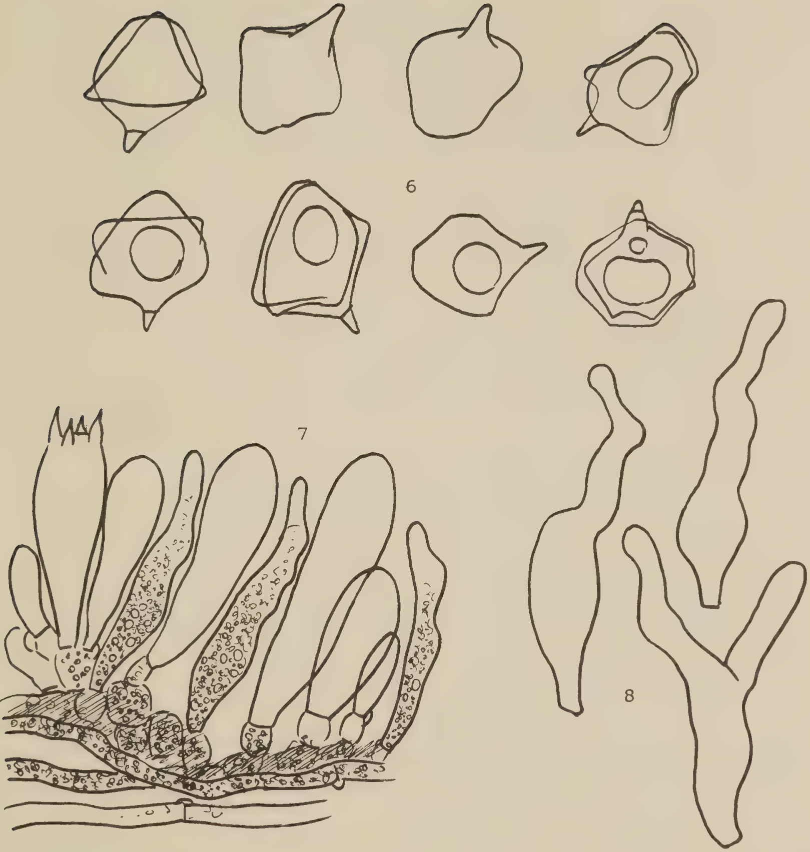


Fig.6-8 - *Entoloma aeruginosum* Hiroe (TMI 4300); 6: Spores; 7:Cheilocystides, Sous-hyménium et trame; 8: Pleurocystides.

tre part, ne soit pas absolument parfaite. Il est néanmoins possible que les spores âgées du type de Berkeley de *Agaricus virescens* soient déformées par rapport à la forme plus complexe qu'elles auraient pu présenter, et aussi que la répartition et l'aspect des pigments puissent être modifiés par une conservation en exsiccatum (*E.aeruginosum*) ou en solution formolique (*R.holocyaneus*).

Il nous semblerait utile de reconsidérer la synonymie ci-dessous, sur la base de comparaisons d'exemplaires frais et en bon état.

Néanmoins, dans l'état actuel des données concernant ces taxons, on peut admettre le point de vue de HORAK et donner la synonymie suivante :

Entoloma virescens (Berk. et Curt.)Horak *comb.nov.*
Basionyme = *Agaricus virescens* Berk. et Curt. 1860 *Proc.Amer. Acad.Arts Sci.* 4:116

= *Entoloma virescens* (Berk. et Curt.)Horak 1976 *Sydowia* 28: 200 (basionyme incomplet et imprécis)
= ? *Entoloma aeruginosum* Hiroe 1939 *Appl.Mushr.Sci.* 4:1
= ? *Rhodophyllus aeruginosus* (Hiroe)Hongo
= ? *Rhodophyllus holocyaneus* Romagnesi 1941 *Prodr.Fl.Mycol.Madagascar* 2:150

Les autres synonymes donnés par HORAK sont : (pas d'échantillons examinés)
= *Cortinarius hochstetteri* Reichart 1866 *Ver.Zool.Bot.Ges. Wien* 16:376
= *Hygrophorus hochstetteri* (Reichart)Reichart 1870 *Reise Fr. Novarra* :144
= *Entoloma hochstetteri* (Reichart)Stevenson 1962 *Kew Bull.* 16:233
= *Hygrophorus cyaneus* Berk. ap.Hooker 1867 *Handb.N.Zeal.Fl.* 2:604
= *Agaricus incanus var. polychrous* Berk. et Br. 1871 *J.Linn. Soc.Bot.* 11:540

Signalons que l'on peut trouver une icone de *Rhodophyllus aeruginosus* (Hiroe)Hongo dans IMAZEKI et HONGO (1957:77).

2. ALBIDUM

a. *Entoloma albidum* Murrill 1917 *N.am.Fl.* 10:119
= *Entoloma cinerascens* Hesler 1967 *Beih.Nov.Hedw.* 23:177
= *Entoloma canum* Hesler 1974 *Mycologia* 66:717

Littérature: HESLER: 1963:318 (type study), 1967:177, 1974:717.

Cette espèce semble bien individualisée.

En 1967, HESLER propose un nouveau nom, *E.cinerascens*, pour éviter la confusion avec *Leptoniella albida* Murrill 1917, qu'il venait de combiner dans le même ouvrage, quelques pages plus tôt, dans le genre *Entoloma*. C'est en fait cette combinaison qui est illégitime (voir ci-dessous), et le nouveau nom proposé est superflu puisque l'*Entoloma albidum* Murrill est le premier a avoir été proposé dans ce genre, et a donc la priorité.

De plus, en 1974, HESLER remplace son *E.cinerascens* par *E.canum*, pour éviter à nouveau une confusion hypothétique avec *Leptonia cinerascens* Velenovski 1921, binôme qui, à notre connaissance, n'a jamais été combiné dans le genre *Entoloma*. *E.canum* est donc un *nomen superfluum* qui en remplace un autre

b. *Leptonia albida* Cleland 1935 *Trans.Proc.Roy.Soc.S.Austral.* 57:189
non *Leptonia albida* (Murrill)Murrill 1917 (voir ci-dessous)

D'après HORAK (1980:313), cette espèce n'appartient pas au genre *Entoloma*.

c. *Leptoniella albida* Murrill 1917 *N.am.Fl.* 10:87

Littérature: HESLER (1963:328, type study, et 1967:27); LARGENT (1974:58 type study et 1977:156).

Nous avons réexaminé le type de cette espèce:

Leptoniella albida Murrill; Type NY 1759; on soil in deep shade. Chapell Hill. September 12, 1915; Coll. H.R.Totten.

Fiche de description manuscrite accompagnant le type: "Cap hemispheritic to convex expanded, up to 2-3 cm wide, slightly umbilicate or depressed in center with a little rounded umbo; margin typically not striate but sometimes with long distant ridges. Surface finely squamulose, dull or shining, color a very light cream tan at maturity, whitish when young. Flesh thin, soft, brittle, whitish, less than 1 mm thick at stem. Taste woody and mildly bitter. Gills not crowded, more or less sinuate, sometimes slightly decurrent by a little tooth, about 5 mm wide near the stem, margin rather regular for the genus, a clear flesh color. Stem 3-6,5 cm long, 1,5-2 mm thick about color of cap all over, smooth, finely granular above, tough, distinctly hollow. Spores salmon flesh color, broadly ellip.irreg., decidedly angular apiculate. rose-coloured: 8-9 X 6 µ.

Nos observations sont les suivantes :

Spores 9-11,5 X 6,5-7,6 µ (+ apicule), à angles nets et saillants, à contour assez courtement elliptique, 5-6-gones (Fig.9).

Sous-hyménium pavimenteux à petites cellules aplaties en 5 à 6 couches.

Trame subparallèle.

Laticifères présents (rares).

Boucles nulles.

Cuticule avec un épicutis présentant des fascicules d'hyphes un peu boudinées à extrémité cylindro-clavée , à pigment vacuolaire (Fig.10); laticifères présents (rares).

Nos mesures de spores sont un peu plus grandes que celles de HESLER et de LARGENT.

Ce taxon, qui semble bien individualisé, entre dans le sous-genre *Leptonia* (Fr.)Noordeloos, section *Paludocybe* (Largent)Noordeloos. Une révision de ce groupe est toujours absente de la littérature, et on ne peut que citer la position que LARGENT attribue à cette espèce, dans la section *Albidicaules* Largent 1974 (*Paludocybe* étant alors au rang de sous-genre).

Un nouveau nom a déjà été proposé pour cette espèce par Morgan-Jones :

Entoloma hesleri Morgan-Jones 1971 *Can.J.Bot.* 49:1052
= *Leptoniella albida* Murrill 1917 *N.am.Fl.* 10:87
= *Leptonia albida* (Murrill)Murrill 1917 *Mycologia* 9:180
= *Entoloma albidum* (Murrill)Hesler 1967 *Beih.Nov.Hedw.* 23:27
non *Entoloma albidum* Murrill 1917 *N.am.Fl.* 10:119

Cependant, le nom *Entoloma hesleri* fut à nouveau employé 5 ans plus tard par Horak pour désigner une autre espèce de Hesler, au nom lui aussi préoccupé: *Entoloma gracile* Hesler. Cette espèce, qui appartient à la section *Staurospori* telle qu'elle est décrite par Romagnesi en 1941 et possède donc des spores "cuboïdes" n'a rien à voir avec *E.hesleri* Morgan-Jones, placé comme nous venons de le voir dans la section *Paludocybe* du sous-genre *Leptonia*.

Nous proposons pour cette espèce le nouveau nom suivant :

Entoloma egonii Courtecuisse *nom.nov.*
= *Entoloma gracile* Hesler 1967 *Beih.Nov.Hedw.* 23:25
non *Entoloma gracile* Stevenson 1962 *Kew Bull.* 16:236
= *Entoloma hesleri* Horak 1976 *Sydowia* 28:216
non *Entoloma hesleri* Morgan-Jones 1971 *Can.J.Bot.* 49:1052

3. CONVEXUM

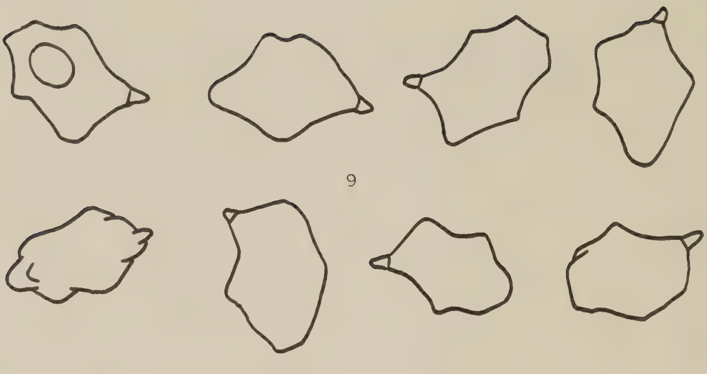
a. *Entoloma convexum* Stevenson 1962 *Kew Bull.* 16:235

Ce taxon est une bonne espèce.
Références: HORAK (1971:425, 1973:28, 1980:136).

b. *Leptonia convexa* Largent 1977 *Bibl.Mycol.* 55:111

Cette espèce est créée en 1977 par LARGENT, ainsi que trois variétés. Elle représente une bonne espèce, et un nouveau nom doit être proposé puisque son introduction dans le genre *Entoloma* est rendue impossible par l'homonyme antérieur sus-cité. Les types de cette espèce et de ses variétés nous ont révélé les caractères suivants:

Leptonia convexa Largent; Type (HSC) DLL 7021; gregarious on needle humus on fallen branches of sitka spruce. Big Lagoon Forest. Humbolt Co., Ca.; 9 Déc. 1974; Coll. and Det.: Largent.



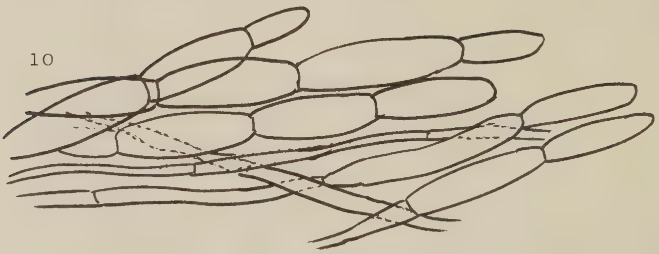


Fig. 9-10 - *Entoloma hesleri* Morgan-Jones (*Leptoniella albida* Murrill - Type NY); 9: Spores; 10:Cuticule.

Spores 8,5-10 X 5,5-6,5 µ, de silhouette elliptique, de forme complexe, à nombreuses facettes plus ou moins bien marquées, avec une dépression supra-apiculaire. Apicule petit. (Fig.11)

Basides 4-sporiques, bouclées, clavées, fines, élancées. (Fig.12)

Boucles présentes, mais assez rares dans la trame.

Sous-hyménium celluleux régulier, à cellules plus ou moins cubiques.

Trame parallèle, à cellules relativement courtes, jusque 45 X 6 µ, plus fines juste sous le sous-hyménium.

Laticifères non observés dans les lames.

Cheilocystides et pleurocystides nulles. Marge garnie de basidioles.

Trame piléique congophobe, à hyphes moyennes ou fines. Epicutis formé de chaînes de cellules cylindracées, jusque 35-60 X 10-21 µ, en fascicules un peu redressées. Pigment vacuolaire. Segment terminal des chaînes d'hyphes non différencié.

Laticifères assez rares dans la cuticule. (Fig.13)

Nous proposons pour cette espèce le nouveau nom suivant :

Entoloma largentii Courtecuisse *nom.nov.*
= *Leptonia convexa* Largent 1977 *Bibl.Mycol.* 55:11
non *Entoloma convexum* Stevenson 1962 *Kew Bull.* 16:235

Leptonia convexa var. badiodorsa Largent; Holotype (HSC) L 3253; scattered in mossy humus beneath Vine mapple and near Douglas fir; Tenino Mounts; Piearce Co., Wash.; 28 Oct.1967.

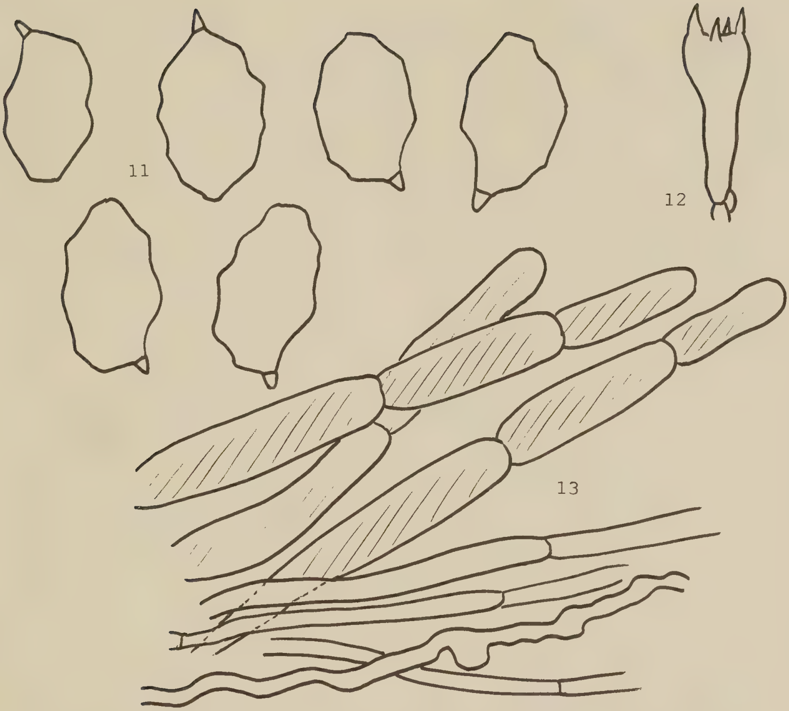


Fig.11-13 - *Entoloma largentii* Court. (*Leptonia convexa* Largent - Type HSC)
11: spores; 12: baside ; 13: cuticule

Spores 8,5-11 X 5,5-6,5-(6,7) µ, de silhouette ellipsoïdale, de forme assez complexe, à angles nombreux et peu marqués. Apicule petit. (Fig.14)

Basides 4-sporiques, bouclées, cylindracées plus ou moins clavées, moyennement trapues (Fig.15)

Boucles présentes dans l'hyménium et le sous-hyménium, nulles ou très rares dans la trame.

Sous-hyménium mince, confus, subcelluleux à pavimenteux.

Trame parallèle à subparallèle, formée d'hyphes moyennes.

Cuticule: Epicutis formé de chaînettes en boudin ou en chapelet de saucisses, en fascicules, à pigment vacuolaire abondant. Eléments souvent courts et trapus, par exemple 30-70 X 10-30 µ (Fig.16)

Laticifères non observés.

La combinaison suivante est proposée :

Entoloma largentii var. badiodorsum (Largent) *comb.nov.*
Basionyme = *Leptonia convexa var. badiodorsa* Largent 1977 *Bibl. Mycol.* 55:114

Le rang variétal semble pouvoir être conservé pour le moment, car plusieurs caractères macroscopiques et écologiques diffèrent par rapport au type (cf. LARGENT l.c.). Sur le plan microscopique, les spores semblent un peu plus longues et les éléments de l'épicutis un peu plus larges.

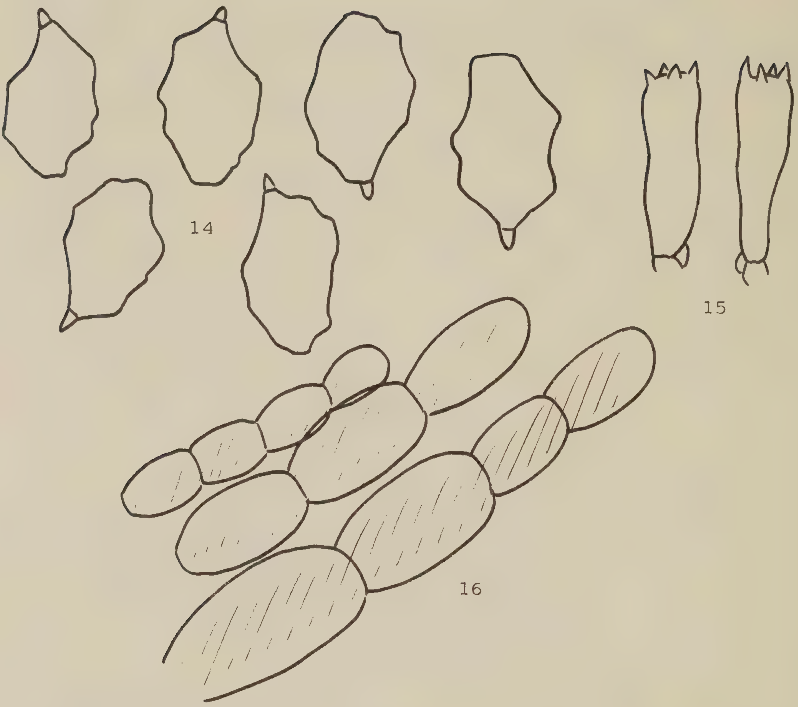


Fig.14-16 - *Entoloma largentii var. badiodorsum* (Largent)Court. (Type HSC)
14: spores, 15:basides, 16: éléments de l'épicutis.

Leptonia convexa var. alnicola Largent; Type (HSC) L 1486; gregarious in a humus of alder leaves; Friday Harbor, San Juan Co., Wash.; 14 Nov. 1965; Coll. and Det.: Largent.

Spores 8-10,5 X 5,5-6,5 µ, de forme elliptique allongée, obscurément anguleuses, de forme complexe, semblant en moyenne les plus étirées du groupe (même si les fourchettes de dimensions sont comparables à celles des autres taxons, le rapport L/l moyen semble plus elevé)(Fig.17)

Basides 4-sporiques, bouclées (Fig.18)

Boucles très rares, sauf au pied des basides.

Sous-hyménium celluleux pavimenteux serré.

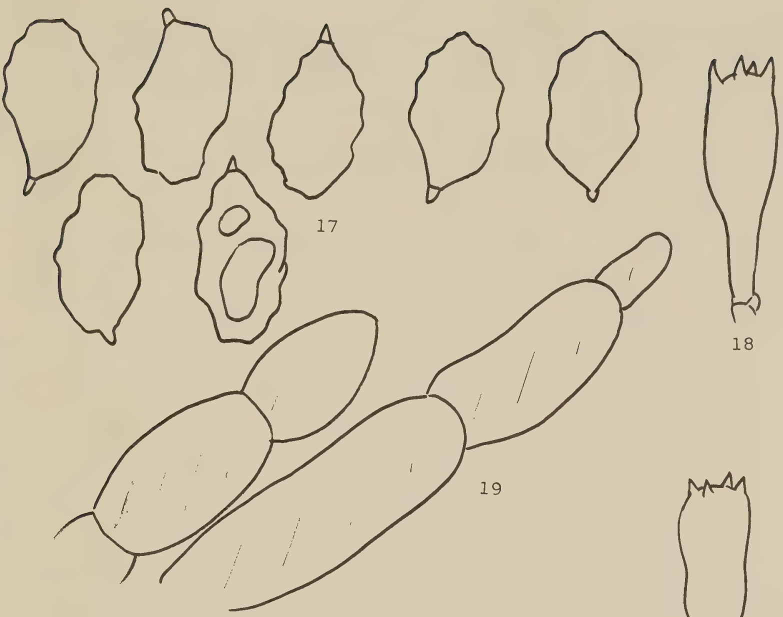
Trame subparallèle. Hyphes moyennes, plus grosses dans la médiostrate.

Cheilocystides et pleurocystides nulles. Laticifères non observés.

Cuticule: Epicutis avec des chaînettes d'hyphes boudinées à éléments souvent très larges, 40-90 X 15-40 µ, en fascicules plus ou moins dressés. Pigment vacuolaire, parfois presque invisible, semblant plus pâle que chez les autres membres du groupe. (Fig.19)

La combinaison suivante est proposée :

Entoloma largentii var. alnicola (Largent)*comb.nov.*
Basionyme = *Leptonia convexa var. alnicola* Largent 1977 *Bibl. Mycol.* 55:115



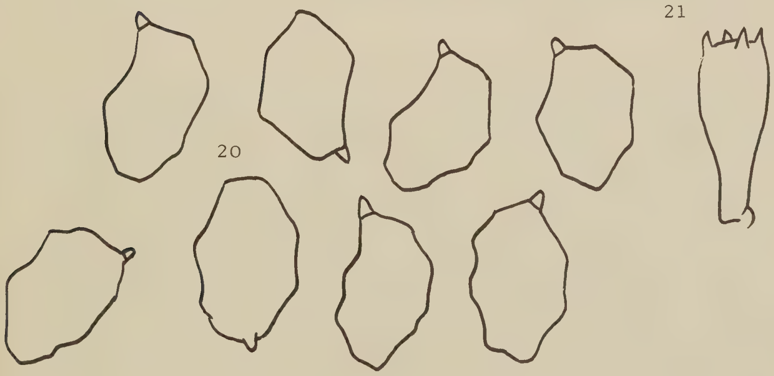


Fig.17-19 - *Entoloma largentii var. alnicola* (Largent)Court. (Type HSC)
17: spores, 18: baside, 19: éléments de la cuticule.
Fig.20-21 - *Entoloma largentii var. farinacea* (Largent)Court. (Type HSC)
20: spores, 21: basides.

Le rang variétal est ici encore conservé, bien que les différences semblent plus importantes par rapport au type que pour la var. *badiodorsum*. L'habitat est caducicole, les spores apparemment plus étirées et plus obscurément anguleuses, les éléments de l'épicutis beaucoup moins pigmentés et plus larges. D'autres récoltes pourraient permettre une élévation au rang spécifique si ces caractères se trouvaient constamment associés.

Leptonia convexa var. farinacea Largent; Type (HSC) DL 3148; solitary in masses near conifers; Ipsut Campground. Mt.Rainier Nat.Park, Piearce Co., Wash. 14.05.1965.

Spores 8-9,5 X 5,5-6-(6,5) µ, de forme ellipsoïde, à angulation assez nette, 5-7-gones, assez proches de celle du type, mais peut-être un peu plus confuses. Apicule petit. (Fig.20)

Basides 4-sporiques, cylindracées, un peu clavées, assez courtes et trapues, bouclées. (Fig. 21)

Boucles très rares ou nulles dans la trame.

Sous-hyménium celluleux à petits éléments serrés.

Trame parallèle à hyphes moyennes.

Cheilocystides et pleurocystides nulles. Laticifères nuls.

Cuticule non observée (exemplaire trop fragmenté).

La combinaison suivante est proposée :

Entoloma largentii var. farinaceum (Largent)*comb.nov.*
Basionyme = *Leptonia convexa var. farinacea* Largent 1977 *Bibl. Mycol.* 55:117

Le rang variétal est conservé, bien qu'il puisse ne s'agir que d'une forme de *Entoloma largentii*. En effet, les spores semblent les plus proches de celles du type. Sur le plan écologique, les conifères forment le dénominateur commun. Néanmoins, nous n'avons pu observer la cuticule de ce taxon, et il semble que les couleurs et l'aspect macroscopique soient quelque peu différents de ceux du type. D'autres récoltes permettront d'apporter un élément de réponse à ce problème.

4. CYANEUM

a. *Agaricus cyaneus* Peck 1873 *Bull.Buff.Soc.Nat.Sci.* 1:49
non *Agaricus cyaneus* Bull. 1783 *Herb.Fr.* n°170 (= *Stropharia*)
= *Entoloma cyaneum* Saccardo 1887 *Syll.Fung.* 5:692 (ut *E.cyaneum* Peck)
= *Leptonia cyanea* ("Peck")Mazzer ap.Largent 1977 *Bibl.Mycol.* 55:66

Sur le plan purement nomenclatural, le basionyme de Peck (1873) étant préoccupé par l'*Agaricus cyaneus* de Bulliard (1783), c'est Saccardo qui endosse la paternité de l'espèce, ayant publié la première combinaison valide.(Art.72.1)

Sur le plan taxonomique, la situation est beaucoup plus confuse. En effet, HESLER (1963:351) synonymise cette espèce avec *Entoloma violaceum* Murrill 1917, mais LARGENT (1977:122) écrit que cette dernière espèce est un *mixtum compositum* formé de l'*E.cyaneum* Sacc. et de *E.porphyrophaeum* (Fr.)Karsten. D'ailleurs HESLER (1963:351) ne note pas de boucles chez *E.violaceum*, alors que le type de *A.cyaneus* Peck en est pourvu (voir plus loin). Nous admettons que *E.violaceum* doit être abandonné en tant que *nomen confusum*.

L'examen du type de *Agaricus cyaneus* nous a revelé les caractères suivants:

Agaricus cyaneus Peck; Type (NYS); Shandaken-Worcester; Leg. C.L.Peck.

Spores petites, ovoïdes, à un peu étirées, 7,5-9,5 X 5,5-6,5 µ (+ apicule).(Fig.22)

Basides bouclées, 4-sporiques, longues, effilées, cylindroclavées.

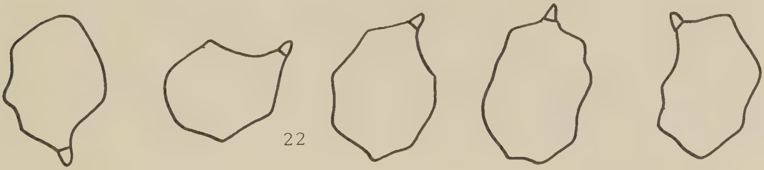
Boucles présentes dans la trame des lames.

Sous-hyménium subcelluleux, plus ou moins coralloïde à coralloïde.

Trame subparallèle à parallèle, à cellules courtes et trapues dans la médiostrate.

Pleurocystides nulles.

Cheilocystides 1- ou 2-cellulaires, en bouquet à l'extrémité de la trame, rendant l'arête stérile, cylindracées à ventrues ou pluriétranglées, 22-45 X 5-8 µ, parfois bouclées. (Fig.23)



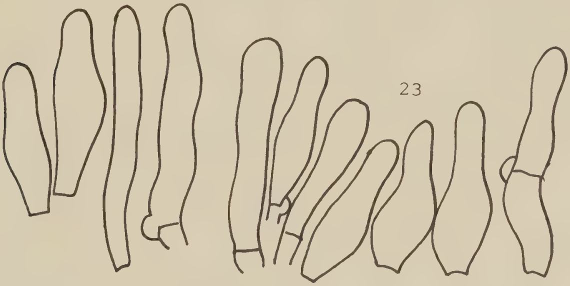


Fig.22-23 - *Entoloma cyaneum* Sacc. (*Agaricus cyaneus* Peck - Type NYS); 22: spores, 23: cheilocystides.

La position taxonomique de cette espèce semble assez claire; une aquarelle figure dans la collection type, qui montre un champignon au pied relativement trapu, épaissi vers la base, de couleur bleu-violet et pâlissant vers le bas où il est lavé de bleuâtre et même de jaunâtre à l'extrême base, et squamuleux au sommet. Les lames sont d'abord blanches et le chapeau est beige-violacé au centre, violet foncé à la marge chez le jeune imbu, et violet opaque au disque, violet foncé à la marge chez l'adulte (sec ?).

LARGENT (1977:68) signale que MAZZER pense que ce champignon est identique à *Entoloma dichroum* (Pers.:Fr.)Kummer des auteurs européens et se range à ce point de vue. Celui-ci nous semble néanmoins difficile à admettre puisque *E.dichroum* n'a pas le pied pelucheux de *A.cyaneus* et que ses spores sont beaucoup plus grandes: (9)-9,3-12 X 7-9,3-(10) µ selon NOORDELOOS (1982:462). Les spores que nous avons mesurées sur le type de *A.cyaneus* sont de taille comparable à celles observées par LARGENT (1977:67). *Entoloma cyaneum* Sacc. se rangerait donc de façon très satisfaisante dans le sous-genre *Leptonia*, section *Leptonia* telle qu'elle est définie par NOORDELOOS (1982: 453) et viendrait à proximité immédiate des espèces du "complexe-*dichroum*" en tant que quatrième membre de celui-ci (avec *E.dichroum*, *E.allochroum* Noord. et *E.tjallingiorum* Noord.) différencié par ses petites spores et aussi par ses caractères macroscopiques qu'il serait d'ailleurs fortement souhaitable de préciser sur du matériel frais.

Il faut encore signaler que LARGENT (1977:66) cite comme synonyme supplémentaire *Leptoniella acericola* Murrill 1917 *N.am.Fl.* 10:88, de même que *Entoloma velatum* Hesler 1967 *Beih.Nov.Hedw.* 23:114, malgré quelques différences micrographiques (spores et/ou cheilocystides, etc...).

b. *Claudopus cyaneus* Murrill 1943 *Mycologia* 35:429
= *Rhodophyllus cyaneus* (Murrill)Singer 1947 *Mycologia* 39:187
= *Entoloma cyaneum* (Murrill)Hesler 1967 *Beih.Nov.Hedw.* 23:13
non *Entoloma cyaneum* Saccardo 1887 *Syll.Fung.* 5:692

Le type de *Claudopus cyaneus* (FLAS 17841) est constitué par une enveloppe dans laquelle se trouvent du sable et des débris ligneux parmi lesquels nous n'avons pas pu trouver de champignon. Nous devons donc nous référer à la description publiée par HESLER (1963:331 et 1967:13). D'après celle-ci, le champignon de Murrill ne semble pas rentrer dans le sous-genre *Claudopus* tel qu'il est défini par NOORDELOOS (1981a:147), mais plutôt, peut-être, dans le sous-genre *Paraleptonia* (Rom.)ex Noord. (l.c.:149), par l'absence de pigment membranaire que l'on peut imaginer puisque Hesler dit (1967:14): "cuticle repent with colourless hyphae".

Les caractères de cette espèce semblent par ailleurs très originaux. La couleur bleue en particulier est remarquable dans les entolomes à "port pleurotoïde" de l'ancien genre "morphologique" *Claudopus*. Cependant, HORAK (1980:33) cite une autre espèce bleue: *Claudopus cyanomelaenus* Boedijn 1929 *Rec.Trav.Bot.Neerl.* 24:419.

Ce dernier taxon rentre beaucoup plus facilement dans le sous-genre *Paraleptonia* (Romagn.)ex Noord. Le pigment vacuolaire est cité dans la diagnose originale, et écarte les *Claudopus ss.str.*

Les deux espèces ne semblent pas différer de façon significative.

Le stipe est très court chez *C.cyanomelaenus* Boedijn: 0,5-1,5 X 0,5 mm, et peut être beaucoup plus long chez *C.cyaneus* Murrill, jusque 3 cm X 1,5 mm (!) d'après HESLER, mais nous nous demandons si ces mensurations ne peuvent pas provenir d'une erreur de transcription, car nous avons noté, sur l'étiquette présente dans le sachet du type: "3 X 1,5 mm".

L'odeur et la saveur sont données comme farineuses pour *C.cyaneus*, mais aucun caractère organoleptique n'est signalé pour *C.cyanomelaenus*.

Les spores sont de dimensions apparemment semblables, puisque HESLER donne tout d'abord (1963:331) 9-10-(12) X 6-7 µ, puis (1967:14) 8-10-(12) X 6-7 µ (il est à noter que le sachet du type renferme une annotation de Hesler, portant: sp. 9-12,5 X 6-7,5 µ !), ceci pour *C.cyaneus* et, que HORAK (1980:33) cite 9-11 X 5,5-6,5 µ pour *C.cyanomelaenum* qui sont les mesures données dans la diagnose originale. De plus, la forme de la spore photographiée par HESLER (1963:356, fig.19) correspond de façon satisfaisante à la fig.9 de Boedijn (1929:418).

Néanmoins, comme nous n'avons pas pu examiner de matériel de ces deux espèces, il semble prématuré de les proposer comme synonymes. Si l'examen des carpophores frais pouvait révéler cette identité, *Claudopus cyanomelaenus* Boedijn 1929 devrait être combiné dans *Entoloma*. Dans le cas contraire, il faudrait proposer un nouveau nom pour le *Claudopus cyaneus* Murrill.

5. FLAVIDUM

a. *Clitopilus flavidus* Massee 1908 *Kew Bull.*:4
= *Entoloma flavidum* (Massee)Corner et Horak ap.Horak 1980 *Beih.Nov.Hedw.* 65:108

Ce taxon, décrit et figuré par HORAK (1980:108) semble assez polymorphe si l'on admet que le type et les exemplaires récoltés à Singapour par CORNER sont conspécifiques.

Le type de cette espèce nous a révélé les caractères suivants :

Clitopilus flavidus Massee; Type (K); Singapour; Ridley 56D (exemplaires très fragmentés !)

Spores 8,5-10 X 6,5-7 µ (+ apicule), assez petites, de forme simple et à angles moyennement marqués (Fig.24).

Basides 4-sporiques, semblant non bouclées (?). L'hyménium s'est montré être en très mauvais état, confus, la majorité des cellules étant collapsées. Boucles non observées avec certitude.

Sous-hyménium semblant plus ou moins coralloïde.
Trame subparallèle à hyphes moyennes à petites.
Arête des lames et cuticule non observées en raison de l'état de fractionnement de l'exemplaire.

Les mesures sporales correspondent à celles données par HORAK, mais sont très différentes de celles de la description originale que nous reproduisons ici :

"Pileus carnosus, e convexo umbilicatus, vel infundibuliformis, margine undulatus vel lobatus, laevis, minute squamulosus, flavidus, 4-5 cm latus. Lamellae subconfertae plus minusve, decurrentes, alboincarnatus, Sporae ellipticae, laxe et minute asperulae, roseotinctae, 6-7 X 4-4,5 µ. Basidia clavata 21-25 X 6-7 µ. Stipes farctus, subfibrillosus basi incrassatus lacunosus, pileo concolor, 3-4 cm longus, 1 cm crassus".

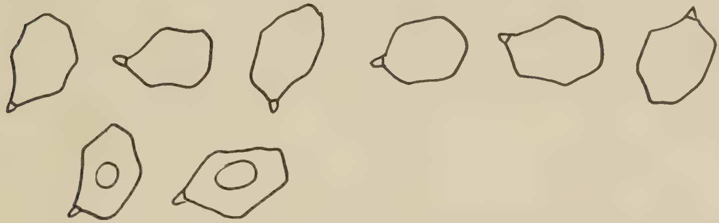


Fig.24 - *Entoloma flavidum* (Massee)Corner et Horak (*Clitopilus flavidus* Massee. Type K), spores.

b. *Eccilia flavida* Peck 1909 *Bull.Torr.Bot.Cl.* 36:153
= *Nolanea flavida* (Peck)Largent 1974 *Northw.Sci.* 48(1):63

Le type de cette espèce nous a révélé les caractères suivants :

Eccilia flavida Peck; Type (NY); Stow.,Mass.; Coll. G.E.Morriss; 11.08.1908

Spores 7,5-9,2 X 5,5-6 µ (+ apicule), allongées, ovoïdes, nettement anguleuses avec une dépression supra-apiculaire souvent nette (Fig.25).
Basides 4-sporiques, non bouclées.
Boucles non observées.
Sous-hyménium subcelluleux, plus ou moins coralloïde à petites cellules serrées.
Trame subparallèle à plus ou moins emmêlée irrégulière.
Pleurocystides nulles.
Cheilocystides rares apparemment, plus ou moins collapsées, de forme générale cylindracée, quelques unes clavées, non mesurables (abimées)(fig.26)

Nous ne connaissons pas les caractères macroscopiques de cette espèce, mais elle semble s'inscrire dans le sous-genre *Nolanea* (Fr.)Noordeloos, section *Endochromonema* (Largent et Thiers)Noordeloos. Les sous-sections *Icterina* Noordeloos et *Cheilocystidiata* Noordeloos pourraient accueillir ce taxon. Aucune espèce ne semble lui correspondre.
Nous proposons le nouveau nom suivant :

Entoloma flavoides Courtecuisse *nom.nov.*
= *Eccilia flavida* Peck 1909 *Bull.Torr.Bot.Cl.* 36:153
non *Entoloma flavidum* (Massee)Corner et Horak ap. Horak 1980
Beih.Nov.Hedw. 65:108

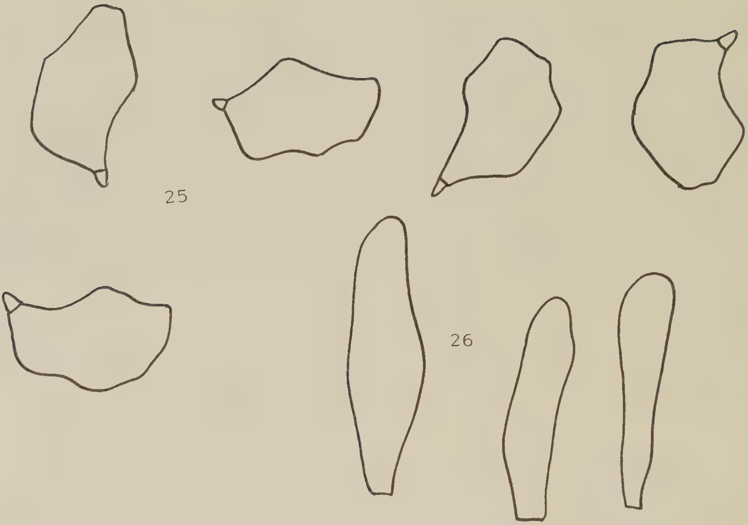


Fig.25-26 - *Entoloma flavoides* Court. (*Eccilia flavida* Peck - Type NY)
25: spores; 26: cheilocystides.

6. MEXICANUM

a. *Eccilia mexicana* Murrill 1917 *N.am.Fl.* 10:85
= *Entoloma subcaeruleum* Hesler 1967 *Beih.Nov.Hedw.* 23:142
= *Leptonia subcaerulea* (Hesler)Largent 1977 *Bibl.Mycol.* 55:132

voir aussi HESLER (1963:339), type study.

b. *Leptoniella mexicana* Murrill 1911 *Mycologia* 3:273
= *Leptonia mexicana* (Murrill)Murrill 1912 *Mycologia* 4:332
= *Entoloma mexicanum* (Murrill)Hesler 1967 *Beih.Nov.Hedw.* 23:95

Nous n'avons pas vu le type de cette espèce, étudié par HESLER (1963:339) puis LARGENT (1977:259) que ce dernier synonymise à *Leptonia undulatella* (Peck)Saccardo. Cependant, les spores telles qu'elles ont été mesurées par HESLER et par LARGENT nous semblent un peu petites par rapport à celles que nous avons observées sur le type de *Agaricus undulatellus* Peck : (7,5)-8-10 X 6-7 µ. Nous préfèrons rester, pour l'instant, prudent quant à cette synonymie.

c. *Rhodophyllus mexicanus* Guzman 1975 *Bol.Soc.Mex.Mic.* 9:63

Le type de cette espèce nous a montré les caractères suivants :

Rhodophyllus mexicanus Guzman; Tipo (ENCB); Carretera Montemorelos à Linares cerca de Arroyo de Encadenados, Nuevo Leon. Agosto 7, 1973; En suelo solitario matorral microfilo con *Telochistes chrysophtalmus* (L.)Th.Fr.; Coll. et Det.: G.Guzman, n°11216.

Spores subsphériques à très légèrement ovoïdes, à angles et facettes nettes, souvent 6-gones, 9,5-10 X 8,5-9,5 µ (+ apicule) (Fig.27).

Basides 4-sporiques, non bouclées. Une sclérobaside observée, un peu plus petite.

Sous-hyménium celluleux, coralloïde à petits éléments noduleux.

Trame subparallèle à hyphes fines. Boucles nulles.

Pleurocystides non observées (les minuscules cystides faciales signalées dans la diagnose latine par Guzman semblent difficiles à voir, ou peut-être diminuer encore de taille sur exsiccata ?)

Cheilocystides plus ou moins lagéniformes, ventrues, plus ou moins mucronées. (Fig. 28)

Cuticule à épicutis plus ou moins hyméniforme, les hyphes terminales étant redressées, cylindro-clavées et obtuses (Fig.29). Pas de boucles.

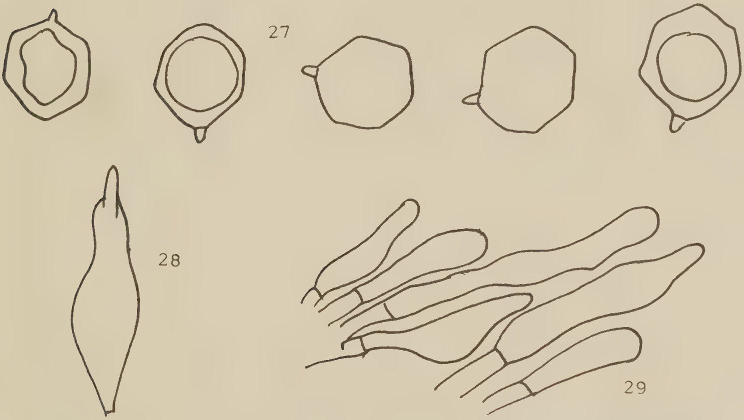


Fig. 27-29 - *Entoloma guzmanii* Court. (*Rhodophyllus mexicanus* Guzman - Type ENCB); 27: spores, 28: cheilocystide; 29: cuticule.

La position taxonomique au sein du genre *Entoloma* (Fr.)Kummer nous semble très originale. Le sous-genre *Allocybe* Noordeloos pourrait convenir d'après la clé présentée par cet auteur (1981b:135), mais la diagnose du sous-genre ne permet pas de confirmer cette appartenance; les boucles sont présentes au pied des basides et la cuticule est un cutis banal. Deux caractères très importants qui séparent le *Rh.mexicanus* Guzman de ce sous-genre.

Aucun taxon supra-spécifique ne semble pouvoir accueillir cette espèce remarquable pour laquelle nous proposons le nouveau nom suivant :

Entoloma guzmanii Courtecuisse *nom.nov.*
= *Rhodophyllus mexicanus* Guzman 1975 *Bol.Soc.Mex.Mic.* 9:63
non *Entoloma mexicanum* (Murrill)Hesler 1967 *Beih.Nov.Hedw.* 23:95

7. TENUIPES

a. *Eccilia tenuipes* Murrill 1917 *N.am.Fl.* 10:82

Références: HESLER (1963:350) type study.

Nous avons examiné le type de ce champignon.

Eccilia tenuipes Murrill; Type (NY 1466); on the ground in oak woods at Bound Brooks (New Jersey); Coll. Earle; 6.07.1903

Une description est donnée sur une fiche manuscrite accompagnant le type: "gregarious. Pileus 1/2 cm, convex umbilicate, tan, glabrous; margin deeply striate; lamellae decurrent, rather broad, pallid to pale pink. Spores pink. Stipe 60 X 1 mm cylindrical glabrous concolorous. Spores obliquely apiculate, rose coloured, 10-12 X 6-8 µ."

Spores 9,5-12 X 7-8,5 µ, de forme assez simple et accusée, ellipsoïde, 5-6-gones, avec un apicule assez volumineux (Fig.30)

Basides 4-sporiques, non bouclées.

Sous-hyménium confus.

Trame subparallèle.

Cheilocystides et pleurocystides nulles.

Boucles nulles.

Cuticule: cutis banal à pigment vacuolaire, formé d'hyphes courtes.

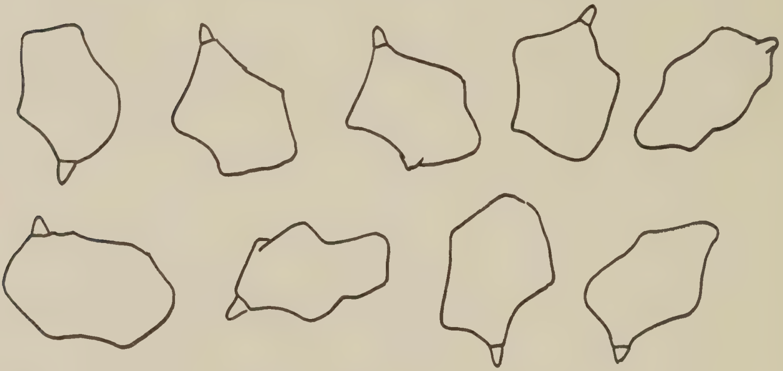


Fig.30: *Eccilia tenuipes* Murrill - Type NY; spores.

La combinaison de caractères: pigment non incrustant et boucles absentes confère à cette espèce une position intéressante et assez difficile à interpréter. La place la plus vraisemblable que l'on puisse lui attribuer semble se situer au sein du sous-genre *Omphalopsis* Noordeloos (= *Eccilia* (Fr.)Q. ss.Romagnesi 1974). Seul *Entoloma omphaliaeformis* (Vel.)Noordeloos semble dépourvu de boucles dans ce sous-genre. La description de Velenovsky (1947:79) et l'étude microscopique de NOORDELOOS (1979:261) ne semblent d'ailleurs nullement en contradiction flagrante avec les renseignements recueillis au sujet du champignon américain de Murrill. Des études complémentaires semblent nécessaires avant de proposer une synonymie entre ces deux taxons ou un nouveau nom pour l'espèce du nouveau continent. Une combinaison dans le genre *Entoloma* serait en effet impossible en raison de l'existence d'un homonyme antérieur (voir ci-dessous).

b. *Entoloma tenuipes* Murrill 1917 *N.am.Fl.* 10:116

Références: HESLER (1963:350)

Cette espèce est de position inconnue, autant que nous le sachions.

c. *Nolanea tenuipes* Orton 1960 *Trans.Brit.Mycol.Soc.* 43:334

Le nouveau nom *Entoloma leptopus* Noordeloos 1980 *Persoonia* 10(4):442 a été proposé pour cette espèce.

Nous menons actuellement une étude comparative entre *E.leptopus* et *E. hebes* (Romagnesi)Trimbach dont les résultats seront publiés ultérieurement.

BIBLIOGRAPHIE :

Berkeley M.T. et M.A. Curtis - 1860 - Characters of new fungi collected in the North Pacific exploring expedition by Ch.Wright. *Proc.Amer.Acad.Arts Sci.* 4:111-130

Boedijn K.B. - 1929 - Beitrag zur Kenntniss der Pilzflora von Sumatra. *Rec. Trav.Bot.Neerl.* 26:396-433

Courtecuisse R. - 1984 - Notes de nomenclature concernant les Hyménomycètes: sur quelques épithètes spécifiques préoccupés. I. *Doc.Mycol.* 54-55:73-92 (Lille - St.Valery sur Somme)

Guzman G. - 1975 - Un nuevo genero y dos nuevas especies de agaricaceos mexicanos. *Bol.Soc.Mex.Mic.* 9:61-66 (Mexico)

Hesler L.R. - 1963 - A study of *Rhodophyllus* types. *Brittonia* 15(4):324-366

Hesler L.R. - 1967 - *Entoloma* in southeastern North America. *Beih.Nov.Hedw.* 23:196 pp. + 240 figs.

Hesler L.R. - 1974 - Name corrections in *Entoloma*. *Mycologia* 66:715-717

Hiroe I. - 1939 - *Entoloma* of Japan (2). Notes on larger fungi on the San-in District (VII). *Appl.Mushr.Sci.* 4(1):1-3

Horak E. - 1971 - A contribution towards the revision of the *Agaricales* (Fungi) from New Zealand. *N.Zeal.J.Bot.* 9:403-462

Horak E. - 1973 - *Fungi Agaricini Neozelandiae*. I. *Entoloma* (Fr.) and related genera. *Beih.Nov.Hedw.* 43:1-86

Horak E. - 1978 - On cuboid-spored species of *Entoloma (Agaricales)*. *Sydowia* 28:171-236 (Horn)

Horak E. - 1980 - *Entoloma* in Indomalaya and Australasia. *Beih.Nov.Hedw.* 65: 352 pp.

Imazeki R. et T. Hongo - 1957 - Coloured Illustrations of Fungi of Japan. Vol.1: 181 pp.

Largent D.L. - 1974 - Rhodophylloid fungi from the pacific coast (United States) IV. Infrageneric concepts in *Entoloma*, *Nolanea* and *Leptonia*. *Mycologia* 66(6):987-1021

Largent D.L - 1974 - Studies in the rhodophylloid fungi. V. *Leptonia* subgenus *Paludocybe* section *Albidicaules* and section *Roseicaules* and related taxa. *Northw.Sci.* 48(1):57-65

Largent D.L. - 1977 - The genus *Leptonia* on the pacific coast of the United States. *Bibl.Mycol.* 55:286 pp. + 94 figs.

Massee C. - 1908 - *Kew Bull.*:4

Noordeloos M.E. - 1979 - Type study in entolomatoid species in the Velenovsky herbarium.I. *Persoonia* 10(2):245-265 (Leiden)

Noordeloos M.E. - 1980 - *Entoloma* subgenus *Nolanea* in the Netherlands and adjacent regions with a reconnaissance of its remaining taxa in Europe. *Persoonia* 10(4):427-534 (Leiden)

Noordeloos M.E. - 1981a- Introduction to the taxonomy of the genus *Entoloma sensu lato (Agaricales)*. *Persoonia* 11(2):121-151 (Leiden)

Noordeloos M.E. - 1981b- *Entoloma* subgenus *Entoloma* and *Allocybe* in the Netherlands and adjacent regions with a reconnaissance of their remaining taxa in Europe. *Persoonia* 11(2):153-256 (Leiden)

Noordeloos M.E. - 1982 - *Entoloma* subgenus *Leptonia* in Northwestern Europe. I. Introduction and a revision on its section *Leptonia*. *Persoonia* 11(4):451-471 (Leiden)

Romagnesi H. - 1941 - Les rhodophylles de Madagascar, *Entoloma*, *Nolanea*, *Leptonia*, *Eccilia*, *Claudopus*, avec une introduction générale sur la classification, la phylogénie, la répartition géographique et la toxicité des *Rhodogoniosporales*. *Prodr.Fl.Mycol.Madag.* 2:164 pp.

Velenovsky J. - 1947 - *Novitates Mycologicae Novissimae*. *Op.Bot.Cech.* 4:167 pp.

MYCOTAXON

Vol. XXVII, pp. 147-153 October-December 1986

TWO NEW DEMATIACEOUS HYPHOMYCETES FROM TROPICAL FOREST LITTER

Laura Zucconi and Silvano Onofri

Laboratorio di Micologia, Dipartimento di Biologia Vegetale,
Università di Roma, Largo Cristina di Svezia 24, 00165 Roma,
Italy

Abstract

Descriptions and illustrations of two new species of Dematiaceous Hyphomycetes, *Circinotrichum flagelliforme* and *Pyricularia sphaerulata*, discovered on tropical forest litter in Ivory Coast, are given.

Two new species of the Dematiaceous Hyphomycete genera *Circinotrichum* Nees (1817) and *Pyricularia* Sacc. (1880) were found on forest litter in the Tai National Park (Ivory Coast).

Circinotrichum flagelliforme sp.nov.

Coloniae hypophyllae, punctiformes, circulares, setis irregulariter dispositis circumdatae, nonnumquam coalescentes, conidiis albae. Mycelium et stroma partim superficialia partim immersa. Setae simplices, erectae, rectae vel modice flexuosae, leves, usque ad 15-septatae, in parte basilari crassitunicatae, brunneae, gradatim angustiores et rarius septatae ad apicem rotundatum, tenuitunicatum, subhyalinum et subtilem; usque ad 900 μm longae et 3.5 μm crassae ad basim (in basi bulbosa 9-14.5 μm crassae). Cellulae conidiogenae polyblasticae, solitariae, percurrenter proliferantes, lageniformes, apice inflato, tenuitunicatae, subhyalinae, parallelae et aggregatae, e stromate subtili superficiali orientes, 7-10 x 2.3-3.5 μm. Conidia hyalina, omnia agglutinata, fusiformia vel subfalcata, basi obtusa et apice tenui praedita, 16-20 x 2.3-2.7 μm.

In foliis emortuis arboris latifoliae, Tai, in Ora Eboris, 18.III.1983, holotypus: ROHB 129A; in foliis emortuis arboris latifoliae, Tai, in Ora Eboris, 18.III.1983, paratypus: ROHB 129A(1)

Colonies hypophyllous, punctiform, roundish, surrounded by irregularly distributed setae, sometimes coalescing to

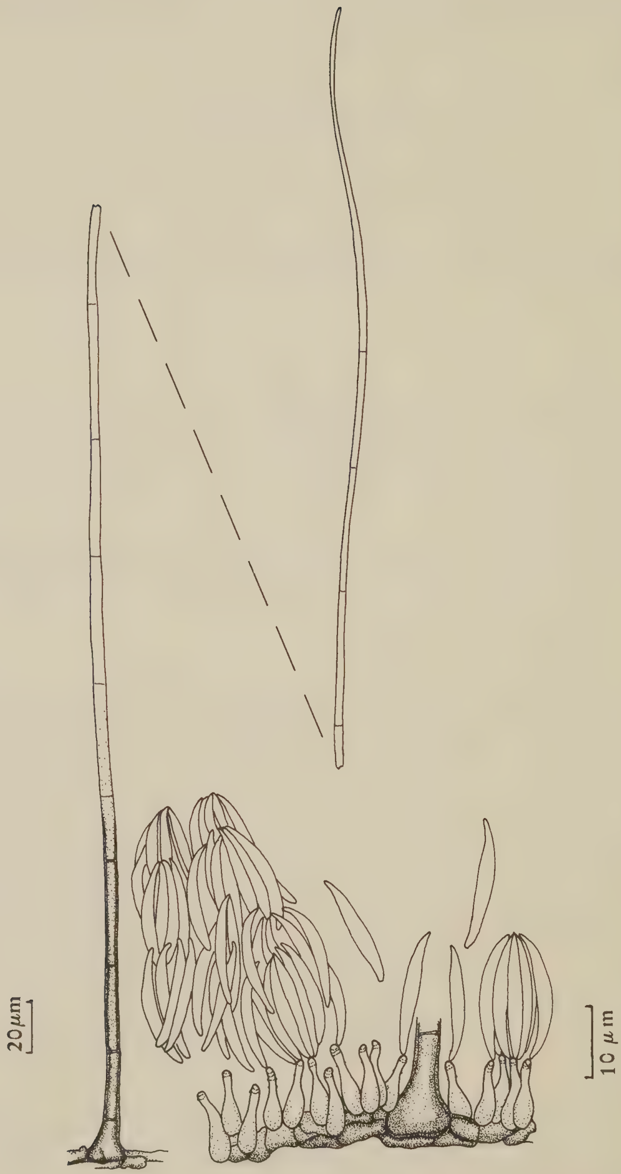


Fig. 1 – *Circinotrichum flagelliforme*: seta, conidiogenous cells and conidia.

form irregular patches, whitish due to sporulation. Mycelium and stroma partly superficial, partly immersed. Setae simple, erect, straight or slightly flexuous, smooth, up to 15-septate, thicker-walled near the base, brown, progressively paler, gradually tapering and less closely septate towards the thin-walled, subhyaline, slender and rounded apex; up to 900 µm long and 3.5 µm wide near the base (9-14.5 µm wide at the bulbous base). Conidiogenous cells solitary, lageniform, swollen at the apex, thin-walled, subhyaline, forming a dense hymenium on the thin and superficial stroma; 7-10 x 2.3-3.5 µm. Conidiogenesis polyblastic with percurrent proliferation. Conidia hyaline, aggregated in slimy masses, fusiform to subfalcate, obtuse at the base and narrowing at the apex, 16-20 x 2.3-2.7 µm.

The morphology of the conidiogenous cells and conidia and the presence of unbranched setae are the main characteristics that allow us to include this species in the genus *Circinotrichum* .

Among the different species described in this genus, only three, *C. papakurae* Hughes & Pirozynski (1971), *C. rigidum* Sutton (1980) and *C. britannicum* P.M. Kirk (1981) possess exclusively straight sterile setae. Our species differs from *C. papakurae* in having much longer and more closely septate setae and conidia different in shape and dimensions. It differs from *C. rigidum* in general morphology and dimensions, moreover this last species is described as phialidic and with conidia bearing at each end a minute appendage. *C. flagelliforme* also differs from *C. britannicum* in having much longer setae and conidiogenous cells and,conidia different in shape and dimensions.

For these reasons we propose *C.flagelliforme* as new species.

Nowadays many different species belong to this genus, but the way in which conidia are formed is a matter of discussion. The only experimental data on conidial ontogeny in the *Circinotrichum-Gyrothrix-Ceratocladium* complex have been published by Cunningham (1974) who describes the conidiogenesis of *G. pediculata*, studied in pure culture by time-lapse observations, as "phialidic sensu stricto". There is no evidence of the presence of phialidic ontogeny in the previously described species of these genera.

Later, Sutton (1980) described the phialidic *C. rigidum*, while also accepting the species *C. fertile* Pirozynski & Hodges (1973) in the genus. The latter is the only species which presents a conspicuous sympodial proliferation.

We don't know if the conidiogenesis in this complex is phialidic, holoblastic sympodial or by successive rings of conidia, as proposed by Pirozynski (1962), but, in our opinion it is problematic to maintain in the same genus phialidic species, as *C. rigidum*, and holoblastic sympodial ones, as *C. fertile*. Therefore, we think that, for the moment, is preferable to accept the combination *Idriella fertilis* (Pirozynski & Hodges) Matsushima (1975) for *C. fertile* to maintain separated the only species that is surely sympodial, which moreover possesses conidiogenous cells and conidia typical of *Idriella* Nelson & Wilhelm.

However the taxonomic rearrangement of this complex awaits further studies on its conidiogenesis.

Pyricularia sphaerulata sp.nov.

Coloniae effusae, amphigenae. Mycelium immersum, conidiophora macronematosa, mononematosa, simplicia, erecta, recta vel modice flexuosa, solitaria, levia, crassitunicata, septata, aureo-brunnea, apicem versus pallidiora et subtilius tunicata, 90-132 x 3.6-4.8 μm; in basi expansa 7.2-12.6 μm lata, septo circumscripta. Cellulae conidiogenae polyblasticae, integratae, terminales, sympodialiter proliferantes, denticulatae, tenuitunicatae; denticuli subcylindrici, ad apicem truncati aperti, ad basim septati; 1-1.4 x 1-1.4 μm. Conidia sicca, solitaria, acropleurogena, levia, 3-septata, fusiformia, sub septo basilari aperta, ad apicem infundibuliformia, sphaerula hyalina (circiter 5.5 μm diam) praedita; pallide olivaceo-brunnea, cellulis terminalibus pallidioribus quam intermediis et protoplasmate granuloso repleta; 27.3-31.5 x 4-4.5 μm (sphaerula exclusa).

In foliis emortuis arboris latifoliae, Tai, in Ora
Eboris, 18.III.1983, holotypus: ROHB 130A

Colonies effuse, amphigenous. Mycelium immersed. Conidiophores macronematous, mononematous, unbranched, erect, straight or slightly flexuose, solitary, smooth, thick-walled, septate, golden-brown, gradually paler and thinner-walled towards the apex, 90-132 x 3.6-4.8 μm; 7.2-12.6 μm wide at the swollen base. Conidiogenous cells polyblastic, integrated, terminal, sympodially proliferating, denticulate, thin-walled; denticles subcylindrical, flat and open at the apex, septate at the base, 1-1.4 x 1-1.4 μm. Conidia dry, solitary, acropleurogenous, smooth, 3-septate, fusiform, with an open-ended base and a funnel-shaped apex, terminating at the tip in a spherical hyaline body (about 5.5 μm diam), light olivaceous-brown, with granular protoplasm and with the end cells paler then the central ones; 27.3-31.5 x 4-4.5 μm (excluding the spherical body).

The conidiophores are pigmented and well developed, the conidiogenous cells are integrated, terminal, sympodially

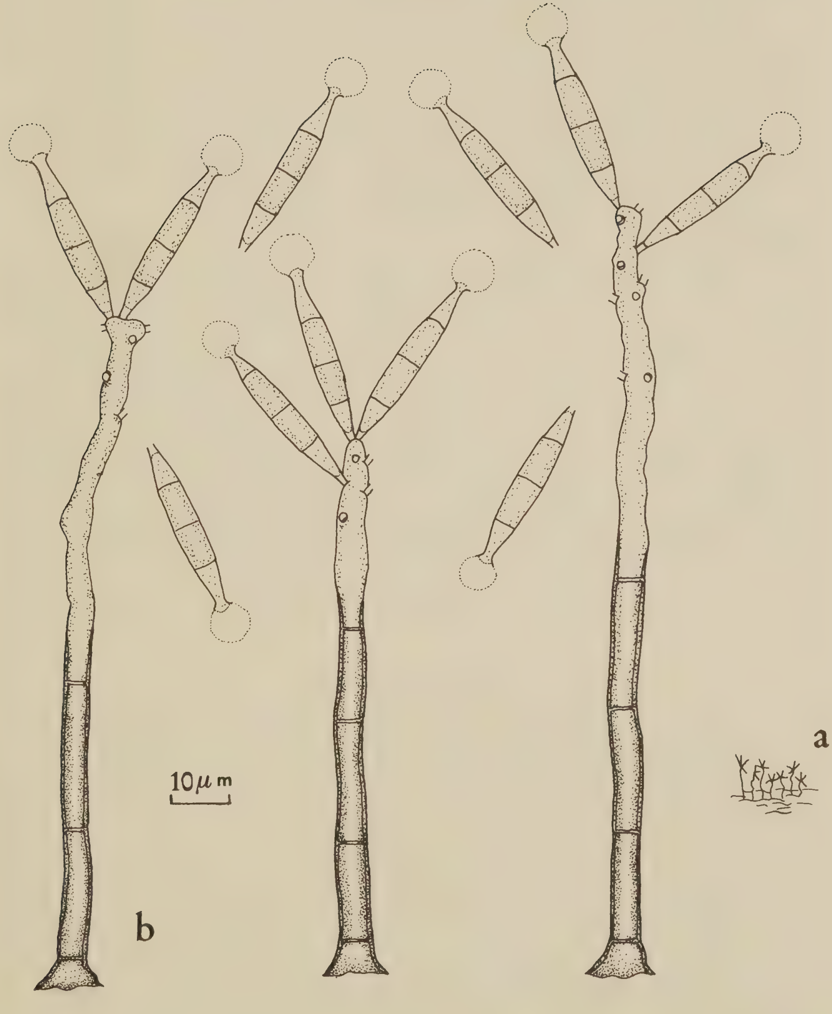


Fig. 2 - *Pyricularia sphaerulata*: a. habit sketch; b. conidiophores and conidia.

proliferating, polyblastic, denticulate. The conidia are shed by the fracture of a small separating cell (rhexolytic secession) which leaves a subcylindrical open-ended denticle on the conidiophore, and an open-ended portion at the base of the conidium. These characteristics allow us to consider the inclusion of this species in *Pyricularia* Sacc..

The fusiform conidia of the Hyphomycete here described exceed the morphological limits of *Pyricularia*, stated as "obclavato-pyriformia" by Saccardo (1880) in the original diagnosis and confirmed by Ellis (1971) as "obpyriform, obturbinate or obclavate". Since then in *Pyricularia* several species have already been included with fusiform conidia, such as *P. fusispora* (Matsushima) Zucconi, Onofri & Persiani (1984), and with ellipsoid conidia, such as *P. lauri* P.M. Kirk (1983).

A distinctive characteristic of this species is the presence of a spherical body at the apex of the conidia. This is less evident in old slides because of its rapid dissolution in lactic acid.

P. buloloensis Matsushima (1971) is the only species published in *Pyricularia* which presents conidia with a similar structure at the tip, described as "calyptra gelatinosa". Our species differs from *P. buloloensis* in the shape and dimensions of the conidia, that are fusiform instead of obclavate and smaller. It also differs in the morphology of the spherical body which is located at the conidial apex and does not surround it. Moreover, in our fungus the body seems to be continuous with the open and swollen apical cell of the conidium.

For these reasons we propose *P. sphaerulata* as a new species.

ACKNOWLEDGEMENTS

The Authors wish to thank the Minister of Scientific Research of the Ivory Coast for the assistance he has given and Dr. W. Gams and Dr. G.S. de Hoog of the C.B.S. for kindly reviewing the manuscript.

REFERENCES

Cunningham, J.L. 1974. A new *Gyrothrix* in culture and a key to species. *Mycologia* 66: 122-129.

Ellis, M.B. 1971. *Dematiaceous Hyphomycetes*. Commonw. Mycol. Inst., Kew, England.

Hughes, S.J. and K.A. Pirozynski. 1971. New Zealand Fungi 15. *Beltraniella*, *Circinotrichum*, and *Gyrothrix*. *N. Z. Jl. Bot*. 9: 39-45.

Kirk,P.M. 1981. New or interesting microfungi III. A preliminary account of microfungi colonizing *Laurus nobilis* leaf litter. *Trans. Br. mycol. Soc.* 77: 457-473.

Kirk, P.M. 1983. New or interesting microfungi X. Hyphomycetes on *Laurus nobilis* leaf litter. *Mycotaxon* 18: 259-298.

Matsushima, T. 1971. *Microfungi of the Solomon Islands and Papua New-Guinea.* Kobe, Japan.

Matsushima, T. 1975. *Icones microfungorum a Matsushima lectorum.* Kobe, Japan.

Nees von Esenbeck, C.G. 1817. *Das System der Pilze und Schwämme, (Ueberblick)*, 86 pp.

Pirozynski, K.A. 1962. *Circinotrichum* and *Gyrothrix*. *Mycol. Pap.* 84: 28 pp.

Pirozynski, K.A. and C.S. Hodges, Jr. 1973. New Hyphomycetes from South Carolina. *Can. J. Bot.* 51:157-173.

Saccardo, P.A. 1880. Conspectus generum fungorum Italiae inferiorum. *Michelia* 2: 135 pp.

Sutton, B.C. 1980. Microfungi from Australian leaf litter. *Proc. R. Soc. Qd.* 91: 11-19.

Zucconi, L., S. Onofri and A.M. Persiani. 1984. Hyphomycetes rari o interessanti della foresta tropicale. II. *Pyricularia fusispora* comb.nov., nuova combinazione per la specie *Nakataea fusispora*. *Micol. Ital.* 2: 7-10.

MYCOTAXON

Vol. XXVII, pp. 155-159 October-December 1986

DIGITATISPORA LIGNICOLA, A NEW MARINE LIGNICOLOUS BASIDIOMYCOTINA

E.B. GARETH JONES

School of Biological Sciences, Portsmouth Polytechnic,
King Henry I Street, Portsmouth, PO1 2DY, England.

While collecting marine fungi on San Juan Island, Washington State, U.S.A., a new Basidiomycotina with tetraradiate basidiospores was encountered (Jones, 1985). This differs markedly from *Digitatispora marina* (Doguet, 1962; Kohlmeyer and Kohlmeyer, 1979), which was also collected at the same site.

DIGITATISPORA LIGNICOLA sp. nov. (Figs. 1-10, 14-15)

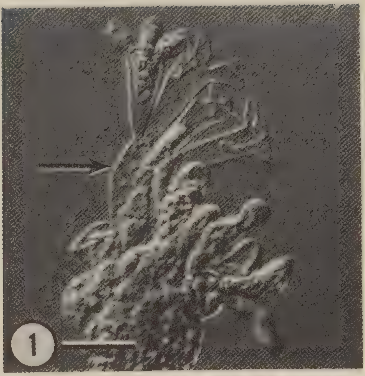
Hyphae 2.5µm diametro, hyalinae, fibuligerae. *Basidiocarpi* 30-120µm alti 0.5mm lati, 1-2mm longi, irregulares, resupinati, albi, molles. *Hymenium* 30-80µm altum, sine cystidiis. *Basidia* 32.3 (45.1) 71.3 x 6.9 (9.8) 10.1µm, 2-4-spora, clavata, erecta, hyalina, sine sterigmatis. *Basidiosporae* tetraradiatae, hyalinae, ramis primis 13.4 (28.5) 41.5 x 5.3 (7.5) 13.8µm, erectis, ad basim attenuatis, ramis lateralibus 6.9 (14.6) 23.0 x 2.8 (3.8) 8.1 µm, ramis vicinis 6.9 (16.6) 25.3 x 2.3 (4.0) 6.9µm, radiantibus et attenuatis. Habitat in ligno. Holotypus IMI 292870.

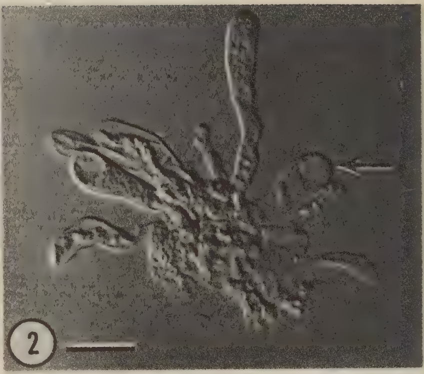
Hyphae 2.5µm in diameter, septate, with clamp connections, hyaline. Basidiocarps 30-120µm high, 0.5mm wide, 1-2mm long, irregular, resupinate, white, soft. Hymenium 30-80 µm high without cystidia. Basidia 32.3 (45.1) 71.3 x 6.9 (9.8) 10.1µm, 2-4 spored, clavate, erect, hyaline without sterigmata. Basidiospores tetraradiate, occasionally with secondary and tertiary branching, hyaline, deciduous, basal arm 13.4 (28.5) 41.5µm x 5.3 (7.5) 13.8µm erect, broad but tapering to the attachment pore to the basidium, apical arms: opposite arm 6.9 (14.6) 23.0 x 2.8 (3.8) 8.1 µm, adjacent arms 6.9 (16.6) 25.3 x 2.3 (4.0) 6.9µm radiating and attenuated.

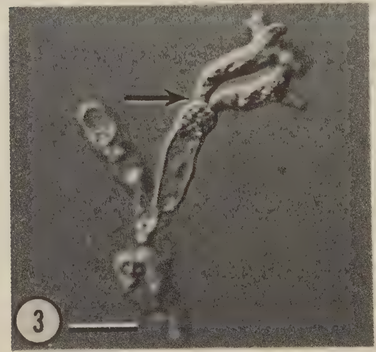
Habitat on driftwood.

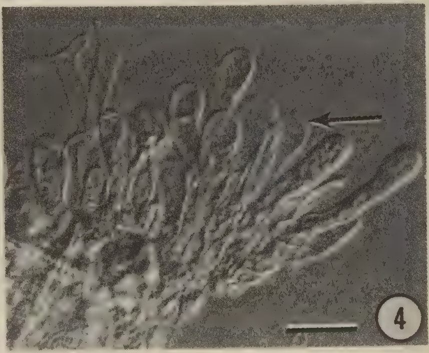
Holotype Herb CMI (IMI) 292870

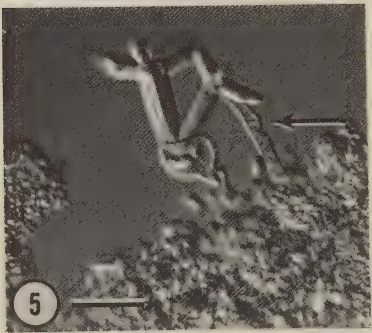
Etymology: Latin *lignum* = wood and *cola* = dweller in reference to the substratum of the species.

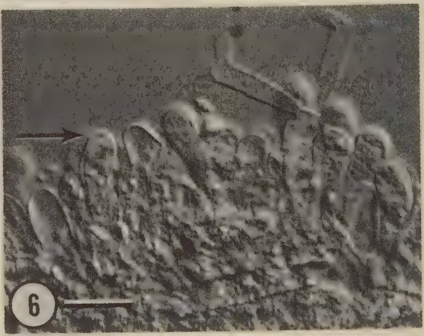

①

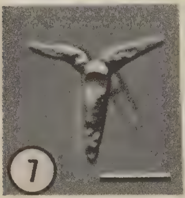

②

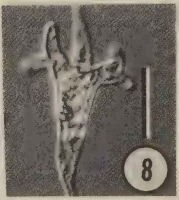

③

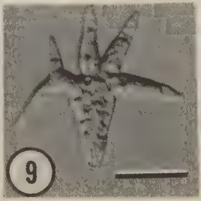

④

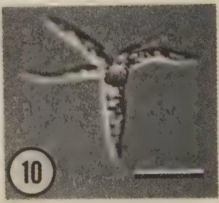

⑤

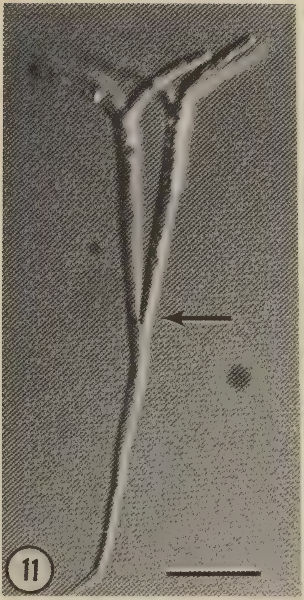

⑥

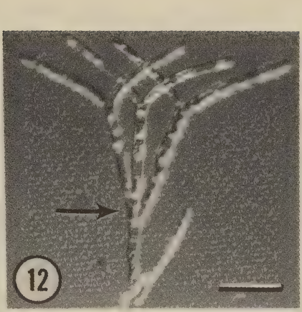

⑦

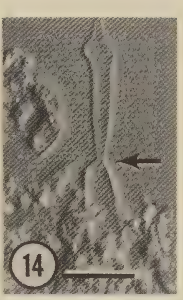

⑧

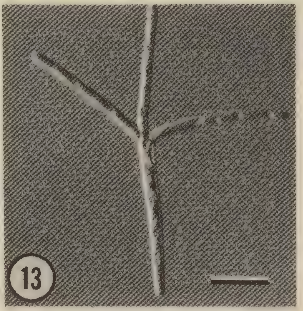

⑨

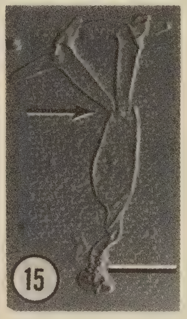

⑩











LEGENDS

Figs. 1-10 *Digitatispora lignicola*. 1, 2, 4, 6. Basidiocarps on wood with club-shaped basidia (arrowed). 3. Basidium with two basidiospores, arrow indicates point of attachment. 5. Basidium with spores and a hypha bearing clamp connections arrowed. 7-10. The tetraradiate hyaline basidiospores, and showing branching of one arm. All interference light micrographs. Bar lines: 20μm.

Figs. 11-13. *Digitatispora marina*. 11,12. Basidia bearing tetraradiate basidiospores, point of attachment arrowed. 13. Basidiospore. Figs. 14-15. *Digitatispora lignicola*. Basidiospore attachment to basidium arrowed. All interference light micrographs. Bar lines: 20μm.

D. lignicola resembles *D. marina* but differs in the following respects:

	D. lignicola	*D. marina*
Basidiocarps	diffuse tufts on wood	irregular but clearly recognisable basidiocarps on wood
Basidia	club-shaped short 32.3-71.3 x 6.9-16.1µm	cylindrical to subclavate 50 x 5-6.5µm
Basidiospores	arms not separated pointed and frequently branched once or twice 18.4-41.5 x 5.3-13.8µm	radiating arm, cylindrical rarely forked 26.5-41 (-45) x 2-3.5µm

The basidia and basidiospores differ in size and morphology and these are considered to be significant at the species level. However, further collections and observations may indicate that these differences are sufficient to warrant separation at the generic level.

This species brings the number of lignicolous marine Basidiomycotina to four although other species have been reported on marine Angiospermae or free floating (yeasts) (Kohlmeyer and Kohlmeyer, 1979). Of the non-yeast Basidiomycotina *Nia vibrissa* and *Digitatispora marina* are the most frequently encountered in temperate locations (Byrne and Jones, 1974; Kohlmeyer and Kohlmeyer, 1979; Jones, Rule and Jones, 1985). In the tropics *Halocyphina villosa* seems to be particularly common on decaying mangrove wood (Kohlmeyer, 1984; Hyde, 1985; Jones, unpublished) and is often the dominant species encountered.

ACKNOWLEDGEMENTS

I am grateful to C. Derrick for photographic assistance, Dr. and Mrs. R.A. Loveless for the Latin diagnosis, the Director and staff of the Friday Harbor Marine Laboratory, University of Washington for laboratory facilities and their help and to the Royal Society for the award of a travel grant from the Marshall and Orr Bequest.

LITERATURE

BYRNE, P.J. and JONES, E.B.G. 1974. Lignicolous marine fungi. Veroeff. Inst. Meeresforsch. Bremerhaven, Suppl. 5: 301-320.

DOGUET, G. 1962. *Digitatispora marina*, n.g., n.sp., Basidiomycete marine. C.R. Hebd. Seances Acad. Sci. 254: 4336-4338.

HYDE, K. 1985. Spore settlement and attachment in marine fungi. Ph.D. Thesis (C.N.A.A.), Portsmouth Polytechnic.

JONES, E.B.G. 1985. Wood inhabiting marine fungi from San Juan Island with special reference to ascospore appendages. Bot. J. Linn. Soc., 91: 219-231.

JONES, E.M., RULE, M. and JONES, E.B.G. 1985. Conservation of timbers of the Tudor Ship Mary Rose. In: Biodeterioration 6, (Ed. S. Barry, D.R. Houghton, G.C. Llewellyn and C.E. O'Rear), Commonwealth Agricultural Bureaux, London (in press).

KOHLMEYER, J. 1984. Tropical marine fungi. Marine Ecology, 5: 329-378.

KOHLMEYER, J. and KOHLMEYER, E. 1979. Marine mycology: The higher fungi. Academic Press, New York, San Francisco, London, 699p.

MYCOTAXON

Vol. XXVII, pp. 161-167 October-December 1986

MARINE FUNGI FROM SEYCHELLES. VI. MASSARINA VELATASPORA A NEW MARINE ASCOMYCOTINA FROM MANGROVE WOOD

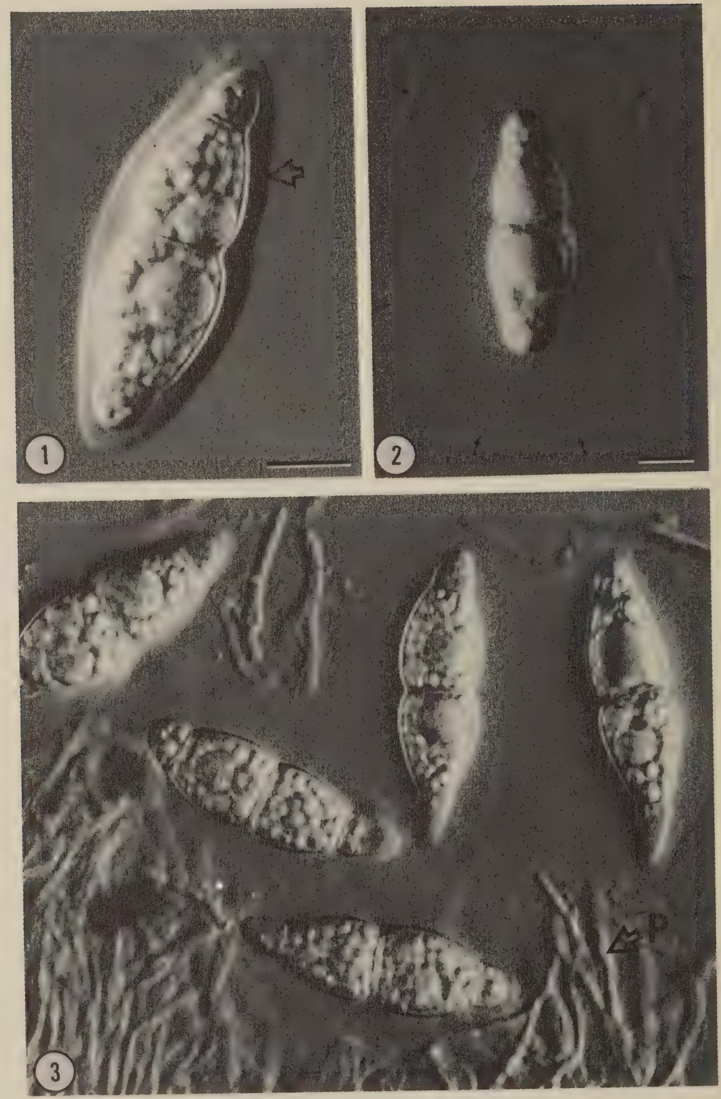
K.D. HYDE[1] and B.D. BORSE[2]

[1] *Department of Biological Sciences, Portsmouth Polytechnic King Henry I Street, Portsmouth, PO1 2DY. England.*

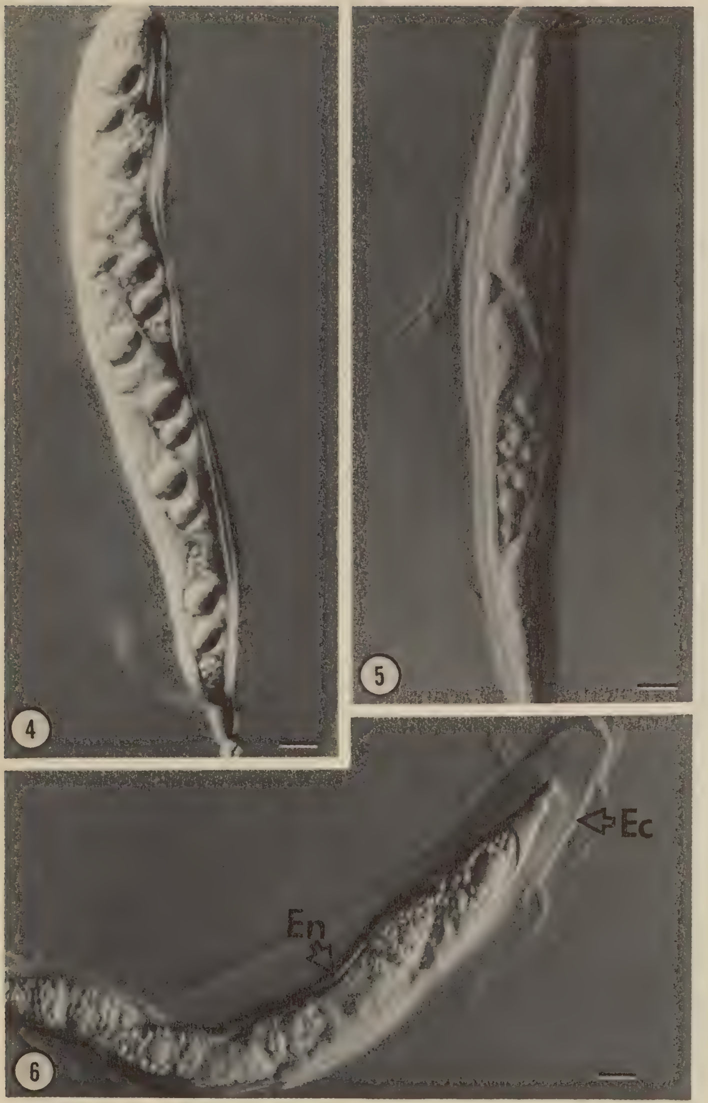
[2] *Department of Botany, Arts, Commerce and Science College, Erandol, 425109, India.*

During a recent study of the marine fungi of the Seychelles, several species were collected from the mangrove ecosystem, which were found to be new to science. Many of these fungi have recently been described: *Aigialus grandis*, *A. parvus*(Kohlmeyer and Schatz, 1985), *Aniptodera mangrovii* (Hyde, Farrant and Jones, 1986), *Caryosporella rhizophorae* (Kohlmeyer, 1985), *Halosarpheia abonnis* (Kohlmeyer, 1984), *Halosarpheia ratnagiriensis* (Patil and Borse, 1982), *Biatriospora marina* (Hyde and Borse, 1986) and *Trematosphaeria lignatilis* (Kohlmeyer, 1984). In this paper a new species belonging to the genus *Massarina* is described. *Massarina velataspora* is characterised by having bitunicate asci, with an apical apparatus, ascospores which are 1-3 septate, hyaline and surrounded by mucilaginous sheath. *M. velataspora* was collected in Seychelles on 9 occasions and was classified by Hyde (1986) as occurring, occasionally. It has also been collected from Maharashtra (India) and Brunei.

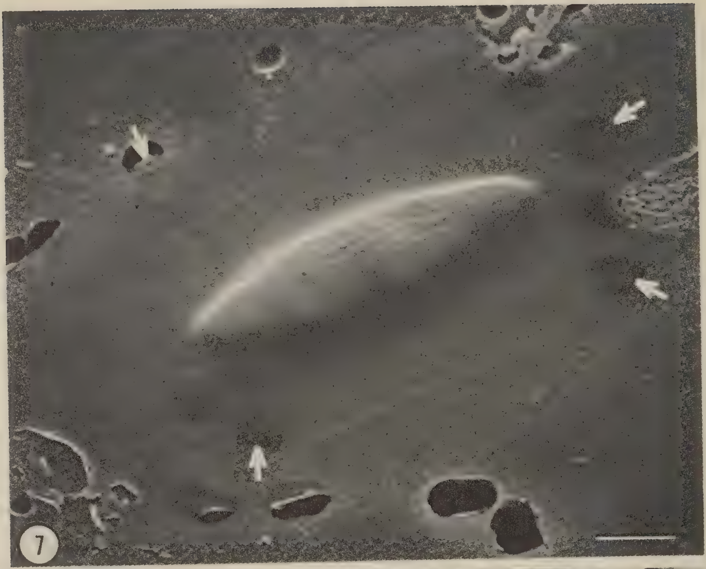
MASSARINA VELATASPORA HYDE et BORSE sp. nov. (Figs. 1-8) *Ascocarpi* 700-(800)-1200μm lati, solitarii vel gregarii, subglobosi, immersi, erumpesdentes, ostiolati, papillati, coriaces, brunnei vel compressi, nigri, ascocarpi expositi hyphis mutis ontecti. *Colla* concia, 55-300μm longa x 60-200μm lata media et nigra. *Pseudoparaphyses* 1.1-1.7μm lati, angusti, hyalini, simplices et numerosi. *Asci* 220-(251)-320 x 23(28.2)-34μm, octospori, cylindrici, parvi, pedunculati, bitunicati, pachydermi, physoclasti, cum apparatu apicali, ad basim ascocarpi orientes. *Ascosporae* 45-(49.5)-56 x 14-(15.9)-19μm, uniseriatae vel biseriatae, fusiformatae vel ellipsoidales, 1-3 septatae, hyaline, constrictione ad septum, cum cellis mediis maioribus, cellis, quando adsunt polaribus parvis et elongatis, ascosporae mucilage circumvelatae.

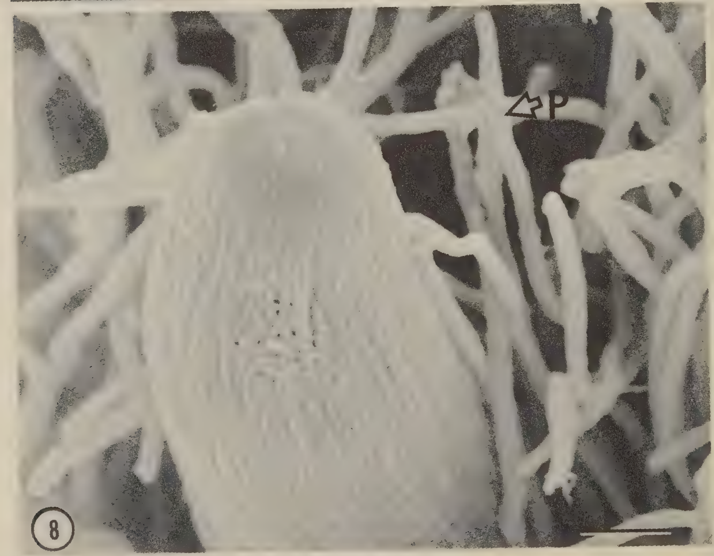


Figs. 1-3 *Massarina velataspora:* light micrographs. 1, 2. Ascospores, 1-3 septate, hyaline, and surrounded by an indistinct mucilaginous sheath (2-arrowed). 3. Squash showing ascospores and pseudoparaphyses (arrowed - 8). Ascospore end cells are small and elongate. Bar lines = 10μm.



Figs. 4-6 *Massarina velatospora*: light micrographs. Asci. Note the apical chamber (arrowed in 5). Spores released by the rupture of the ectoascus (EC) and the stretching of the endoascus (En). Bar lines = 10μm.





Figs. 7, 8. *Massarina velatospora:* Scanning electron microscope micrographs. 7. Ascospores settled on a polycarbonate membrane - mucilaginous sheath extends over pores (arrowed) in the membrane. 8. Ascus tip surrounded by filamentons pseudoparaphyses. Bar lines = 10μm.

Coloniae in agaro cum corn-mealo et aqua maris composito floccosae crescentes, albae, purpureae maturescentes, et agarum colorantes purpuram. Structuras similes pycidiorum formantes quae maturescentes non visae sunt. *Substratum* lignum mortuum. *Distributio* Oceanus Indicus (Seychelles, India), Mare Chinese Austrum (Brunei).

Ascocarps 700-(870)-1200µm in diameter, immersed, becoming rumpent, subglobose or depressed, ostiolate, papillate, coriaceous, brown to black, solitary or gregarious, exposed tissue covered in a fine hyphal mat. *Necks* 55-300µm high x 60-200µm in diameter, central and black. *Pseudoparaphyses* 1.1-1.7µm in diameter, filamentous, hyaline, simple and numerous. *Asci* 220-(251)-320 x 23-(28.2)-34µm, 8-spored cylindrical, short pedunculate, bitunicate, thick-walled, with an apical apparatus, and developing at the base of the ascocarp venter. *Ascospores* 45-(49.5)-56 x 14-(15.9)-19µm, uni-seriate, fusiform, to ellipsoidal, 1-3 septate, hyaline, constricted at the septa, central cells larger, apical cells when present small and elongate, surrounded by an indistinct mucilaginous sheath, 5-22µm wide. Colonies on sea water cornmeal agar, floccose, at first white becoming purple with age, and staining the medium purple. Forming pycnidial-like structures, which were not observed to mature. *Substrate* intertidal mangrove roots and branches of *Rhizophora mucronata*. *Range*. Indian Ocean (Seychelles, India) and South China Sea (Brunei). Type material: January 1984, Herb. IMI 297770, slides 1-10 (Holotype) and dried wood (Isotype).

Etymology: From the Latin, *velata* = a wrapping or envelope, in relation to the envelope of mucilage sheathing the spore and *spora* = spore. The species belongs in the Pleosporales, Massarinaceae, and in the genus *Massarina* as it has fusiform-ellipsoidal ascospores, which are hyaline, 1-3 septate and surrounded by a mucilaginous sheath (Figs. 1-3). *Asci* are 8-spored, cylindrical and bitunicate (Figs. 4-6). A number of aquatic *Massarina* species have been reported: *M. cystophorae* (Cribb et Herbert) Kohlm. et Kohlm. (Kohlmeyer and Kohlmeyer, 1979); *M. aquatica* Webster (Webster, 1965); *Massarina* sp. (Webster and Descals, 1979). *M. velatospora* differs from the only known marine species, *M. cystophorae* in spore size, the latter only has cap-like gelatinous appendages and is parasitic on the brown algae *Cystophora retroflexa* and *C. subfarcinata*.

Measurements of aquatic *Massarina* sp.(μm).

	Ascocarps	Asci	Ascospores
M. cystophorae	650-950 x 650-1000	105-150 x 50-64	50-65 x 16-23
M. velatospora	700-1200	220-320 x 23-34	45-56 x 14-19
M. aquatica	300-500	110-130 x 10-12.5	25-30 x 5-7
Massarina sp.1	120-240	96-120 x 9-10	22-24 x 7-9
Massarina sp.2	140-260	68-82 x 11-12	20-24 x 2-5

Many marine fungi have been shown to have mucilaginous sheaths: *Leptosphaeria contecta* Patouillard, *Pleospora guadefroyi* Kohlm. (Kohlmeyer and Kohlmeyer, 1979), and *Nimbospora bipolaris* Hyde et Jones (Hyde and Jones, 1985). Of the marine fungi associated with mangroves, a mucilaginous sheath has also been noted in *Leptosphaeria avicenniae* Kohlm. et Kohlm. (Kohlmeyer and Kohlmeyer, 1979). Hyde, Jones and Moss,(1986a,b), have suggested that mucilaginous sheaths aid in the attachment of spores to surfaces. Fig.7 shows the mucilaginous sheath of *M. velatospora* which is amorphous, almost electron transparent and closely adpressed to the polycarbonate membrane. Undoubtedly the presence of a sheath increases the surface area of the spore and thus enhances the spore attachment. Similar observations have been made for *Leptosphaeria contecta*, spores becoming readily attached to glass slides. The sheath also causes the ascospore to float on the surface of water, the sheath "sticking" to the surface film on the water. This may also be advantageous to the ascospore, which will float on the incoming and outgoing tides, or be wind blown and be dispersed in this manner.

ACKNOWLEDGEMENTS

K.D. Hyde is grateful for the award of an SERC studentship, and also to CIBA-GEIGY A/S, Basle, for financial support to visit the Seychelles. We are also indebted to C. Derrick for photographic assistance, P. Crook for assistance in the Seychelles, Mrs. Monica Heywood-Kenny for the Latin diagnosis and to Professor E.B.G. Jones for his encouragement and also reviewing the manuscript.

LITERATURE CITED

HYDE, K.D. 1986. Frequency of occurrence of lignicolous marine fungi in the tropics. In: "Biology of Marine Fungi" (Ed. S.T. Moss), pp.311-322, Cambridge, Cambridge University Press.

HYDE, K.D. and BORSE, B.D. 1986. Marine fungi from Seychelles. V. *Biatriospora marina* from mangrove wood. Mycotaxon, 26: 263-270.

HYDE, K.D. and JONES, E.B.G. 1985. Marine fungi from Seychelles. I. *Nimbospora effusa* and *Nimbospora bipolaris* sp. nov. from driftwood. Can.J.Bot., 63: 611-615.

HYDE, K.D., FARRANT, C. and JONES, E.B.G. Marine fungi from Seychelles. III. *Aniptodera mangrovii* from mangrove wood. Can.J.Bot., (in Press).

HYDE, K.D., JONES, E.B.G. and MOSS, S.T. 1986a. How do fungal spores attach to surfaces? In: Biodeterioration 6, (Eds. S. Barry, D.R. Houghton, G.C. Llewellyn and C. O'Rear), London, Commonwealth Agricultural Bureaux, (in Press).

HYDE, K.D., JONES, E.B.G. and MOSS, S.T. 1986b. Mycelial adhesion to surfaces. In: "Biology of Marine Fungi" (Ed. S.T. Moss), pp.331-340, Cambridge, Cambridge University Press.

KOHLMEYER, J. and KOHLMEYER, E. 1979. Marine Mycology. The Higher Fungi. New York, Academic Press; 690 pp.

KOHLMEYER, J. 1984. Tropical marine fungi. Marine Ecol., 5: 329-378.

KOHLMEYER, J. 1985. *Caryosporella rhizophorae* gen. et sp. nov. (Massariaceae), a marine Ascomycete from *Rhizophora mangle*. Proc.Indian Acad.Sci.(Plant Sci.), 94: 355-361.

KOHLMEYER, J. and SCHATZ, S. 1985. *Aigialus* gen. nov. (Ascomycetes) with two marine species from mangroves. Trans. Br.mycol.Soc., 85: 699-707.

PATIL, S.D. and BORSE, B.D. 1982. Marine fungi from Maharashtra (India) I. The genus *Halosarpheia* J. and E. Kohlmeyer. Indian Bot. Reptr., 1: 102-106.

WEBSTER, J. 1965. The perfect state of *Pyricularia aquatica*. Trans. Br. mycol. Soc., 48: 449-452.

WEBSTER, J. and DESCALS, E. 1979. The teleomorphs of water-borne hyphomycetes from fresh water. In: The Whole Fungus, Vol.2, (Ed. B. Kendrick), pp.419-451, Ottawa, National Museums of Canada and The Kananaskis Foundation.

MYCOTAXON

Vol. XXVII, pp. 169-182 October-December 1986

TAXONOMIC CONCEPTS IN THE ENDOGONACEAE: III. THE SEPARATION OF *SCUTELLOSPORA* GEN. NOV. FROM *GIGASPORA* GERD. & TRAPPE

CHRISTOPHER WALKER

Forestry Commission, Northern Research Station, Roslin, Midlothian, EH25 9SY, UK

and

F. E. SANDERS

Department of Plant Sciences, University of Leeds, Leeds, LS2 9JT, UK

SUMMARY

The genus *Gigaspora* is split into two genera, *Gigaspora* Gerd. & Trappe emend. Walker & Sanders and *Scutellospora* gen. nov. This separation is based principally on details of spore germination, although other characteristics are also used. The factors that characterise and separate the two genera are detailed.

The genus *Gigaspora* Gerd. & Trappe was erected to contain fungi in the Endogonaceae which form arbuscular mycorrhizas and produce spores on a bulbous suspensor-like cell (Gerdemann & Trappe 1974) (Fig. 1). The genus originally included five species, and a further 18 have since been added (Becker & Hall 1976; Hall 1977; Nicolson & Schenck 1979; Ferrer & Herrera 1981; Bhattacharjee *et al.* 1982; Schenck & Smith 1982; Koske, Miller & Walker 1983; Hall & Abbott 1984; Koske & Walker 1984, 1985). Observations of spore wall structure, germination characteristics of the spores, and ornamentation of auxiliary cells (terminology of Trappe & Schenck (1982)), show that there are two distinctive groupings within the genus (Walker 1985; Walker & Sanders 1985). These differences form a clear and consistent dichotomy of *Gigaspora sensu lato* and it is appropriate to assign each of the groupings to a different genus.

The term *azygospore*, used by some authors for the large spores of *Gigaspora* carries with it the connotation of asexuality. While we do not consider there is, as yet, evidence for a sexual process in the formation of these spores, neither do we know of any evidence to indicate that they are indeed asexual. Thus we prefer to avoid the use of *azygospore*, choosing simply to refer to them as *spores*. This is in agreement with the usage of Koske *et al.* (1983), where the use of the term was questioned in the description of *G. reticulata* Koske, Miller & Walker, and of Koske & Walker (1984, 1985), where it was dropped without comment.

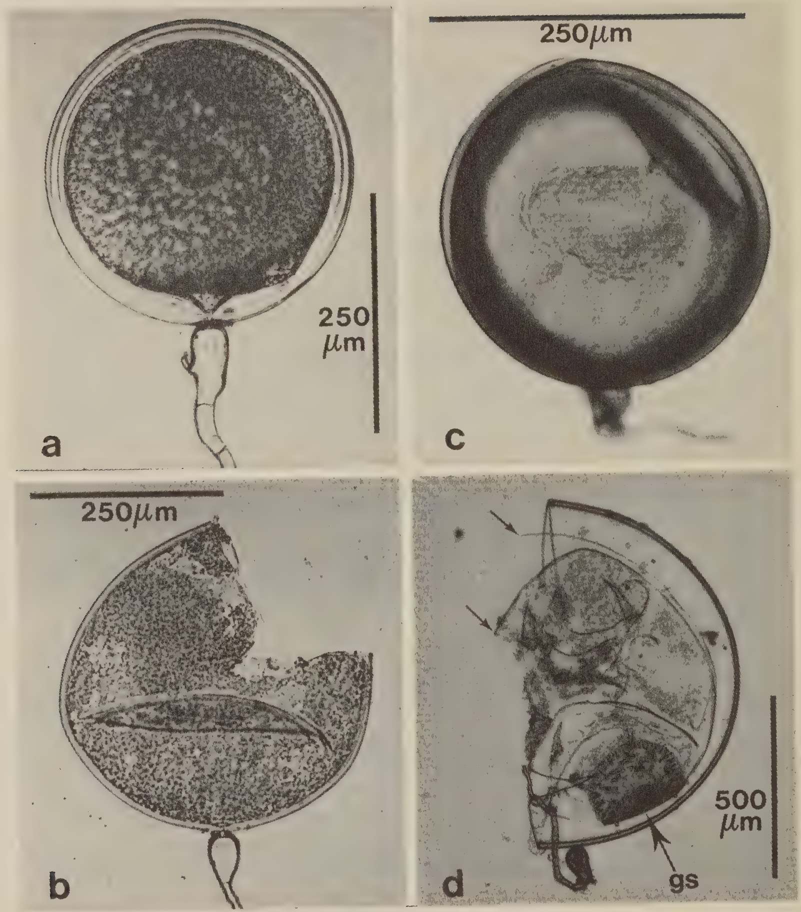


Fig. 1: Spores of species of *Gigaspora* Gerd. & Trappe. Note the typical bulbous suspensor-like cell upon which the spore is borne.

a) Intact spore of *G. margarita*, a species with only a single wall group, lacking the flexible inner walls illustrated in Fig. 1c & d.

b) A crushed spore of *G. margarita*. Note the lack of membranous inner walls.

c) A species of *Gigaspora sensu lato* (*G. heterogama*) that possesses an inner wall group with flexible inner walls, detectable in this intact spore by the plasmolysis at upper right.

d) This crushed specimen of an undescribed species of *Gigaspora sensu lato* has flexible inner walls (small arrows) forming an inner wall group. The spore also has a distinct germination shield (gs).

On another matter of terminology, in the literature on the Endogonaceae, the term 'spore' has generally been used in a rather broad and uncritical manner. For example, the so-called 'spores' of members of the genus *Endogone* are, in reality, zygosporangia enclosing a zygospore (Berch & Fortin 1982). Whether the 'spores' of species of *Gigaspora sensu lato* should be considered also to be sporangia (as suggested by Gibson (1985)) enclosing a single spore remains moot, but those herein placed in the new genus *Scutellospora* do seem to produce a definite endospore. Nevertheless, we shall retain the traditional usage of the term 'spore' in this paper.

Wall structure

The terminology of Walker (1983, 1986) will be used in discussion of spore wall characteristics. Spores formed by species of *Gigaspora sensu lato* can be classified into one of two types, those that have one or more flexible inner walls and those that do not. This dichotomy can be inferred from the original descriptions in Nicolson & Gerdemann (1968), though these authors made no comment on the matter. Spores of species such as *G. gigantea* (Nicol. & Gerd.) Gerd. & Trappe have only a single wall group which usually consists of an outer, unit wall, tightly adherent to an inner, laminated wall. Although they must have a plasmalemma, they do not possess flexible inner walls, either membranous or coriaceous. In contrast, although spores of species typified by *G. calospora* (Nicol. & Gerd.) Gerd. & Trappe may have an outer wall structure similar to that of *G. gigantea*, they invariably also have at least one inner wall group, consisting of at least one membranous or coriaceous wall. This inner wall group seems to form a complete endospore that becomes detached at the spore base at maturity, and which usually can be readily separated from the other walls. Both spores of the *G. gigantea* type and those of the *G. calospora* group share the possession of a thin inner wall layer, adjacent to the plasmalemma, which is approximately 0.07 μm in thickness, and thus is not resolvable by light microscopy. This layer is attached to the outer wall group in the former, and the inner wall of the innermost wall group in the latter (Gibson 1985).

Germination characteristics

The germination characteristics of spores in *Gigaspora sensu lato* are linked closely with the differences in wall structure. Spores of the *G. gigantea* group germinate by production of one or more germ tubes directly through the spore wall, normally at a point near the suspensor-like cell's attachment, after the formation of a warty ring on the interior of the laminated wall (Fig. 2). This mode of germination, discussed and illustrated for *G. margarita* Becker & Hall by Sward (1981), will be referred to as *direct germination*. The *G. calospora* group has an entirely different, and much more complicated method of germination. The germ tube emerges through the outer wall in a manner superficially similar to direct germination, but it does not originate from the outer wall group. It emerges from a specialised structure formed within one of the flexible walls in the inner group, the development of which is not fully elucidated. Light-microscope studies and examination of whole and crushed or dissected spores of several species and examination of electron micrographs of *Gigaspora heterogama* (Nicol. & Gerd.) Gerd. & Trappe (Gibson 1985) leads us to infer the following mode of formation (Fig. 3). Initially, a hole appears in a wall of the inner wall group, through which the cell plasma membrane protrudes. The extruding membrane then

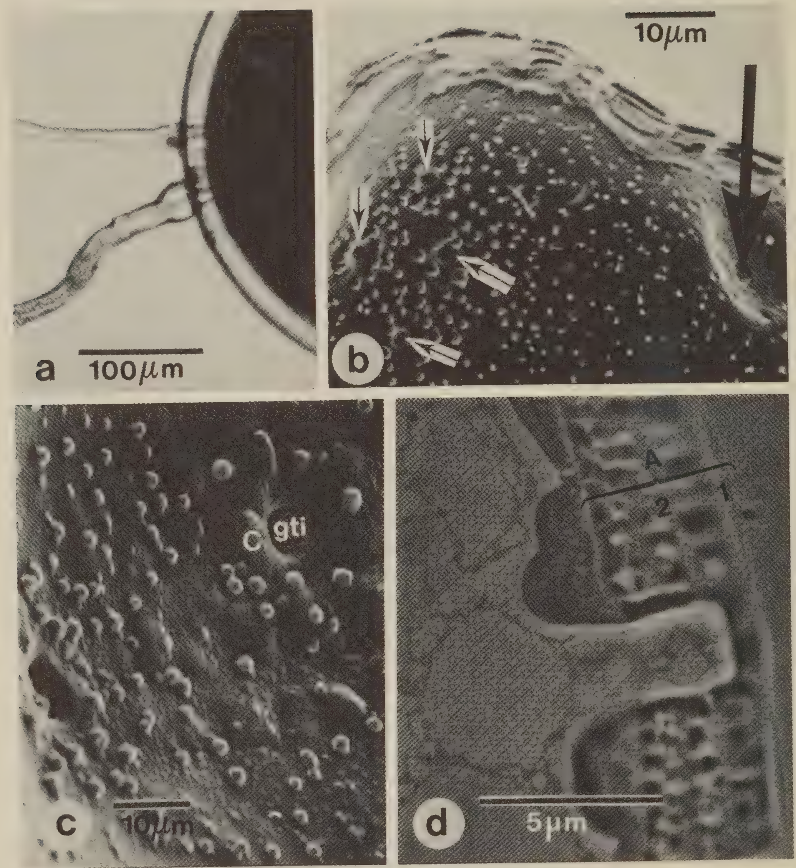


Fig. 2: Direct germination in spores of *Gigaspora sensu lato*.

a) Two germ tubes emerging directly through the spore wall of a *G. margarita* spore.

b) Scanning electron micrograph (SEM) of the inside of a spore with direct germination. The point of attachment of the suspensor-like cell can be seen at upper right (large arrow). Four sites of germ tube initiation can be seen at lower left (small arrows).

c) Detail of two of the germ tube initiation points in Fig. 2b. Note the build-up of wall material to form a collar (C) around the germ tube initial (gti).

d) Germ tube initial in cross section by light microscopy, showing build-up of collar material around the lumen of the germ tube initial. The relatively simple wall structure of a unit wall (1) and a laminated wall (2) in a single group (A) is illustrated.

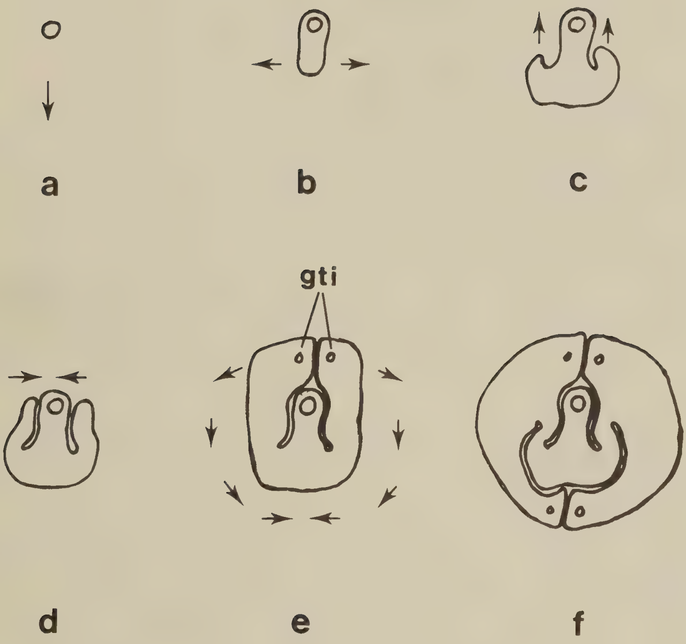


Fig. 3: Diagrammatic representation of the stages in germination shield formation (in plan view). The figure should be viewed as if the paper were a flexible (membranous or coriaceous) inner wall and the outer wall group was not present. The arrows indicate direction of growth and folding of the cell wall as the next stage of development proceeds.

a) A hole appears in the flexible wall.

b) The plasma membrane extrudes and extends, sandwiched between inner and outer wall groups.

c & d) Growth and development takes place as the two lobes of the germination shield are formed.

e) In the simplest form of germination shield, the two lobes meet and a germ tube initial (gti) is formed in each lobe. Wall material is deposited to complete the germination shield.

f) In a more complex germination shield, further lobes are formed which meet and from which germ tubes may also emerge. Yet more complex forms with several lobes can be found in some species.

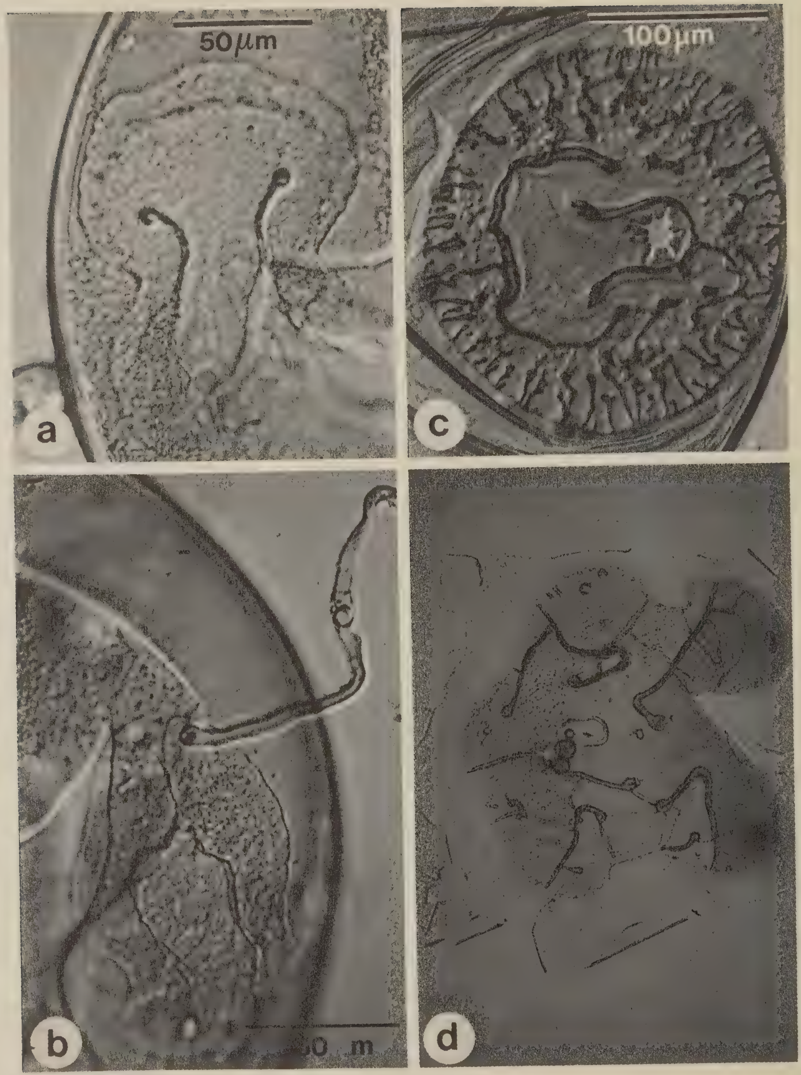


Fig. 4: Light micrographs of germination shields in two species of *Gigaspora sensu lato*.

a & b) Plan views of the simplest form of germination shield from spores of *Gigaspora calospora*. The lobe on the right side is damaged and somewhat displaced in a. A germ tube is emerging from the lobe on the right in b.

c & d) Plan views of complex forms of germination shield with several lobes; c. is *G. nigra* and d. is an undescribed species from Nigeria.

folds back on itself to produce a characteristic 'wishbone' formation. The lobes thus formed meet in a pincer-like configuration reminiscent in plan view of the suspensor cells of a zygospore, but without the spore between them. The structure thus formed is constrained by its juxtaposition between the inner and outer wall groups, into the shape of a convex, more or less discoid shield. Additional wall material is then deposited to encompass this shield, thickening around the edges and folds. In section, the shield then appears to be formed within the membranous wall. This material appears to be the same as that of the membranous wall in some species, but in others may be brittle. In such instances, it may also be pigmented. Two germ tube initials then form, one on each side of this pincer-like arrangement. A germ tube then arises, often from only one of these initials, and emerges through the outer spore walls.

In its simplest form (found, for example on *G. calospora* and *G. heterogama*), there is no further division (Fig. 4a), but in some species, new lobes form repeatedly, dividing the structure into several compartments, each with a germ tube initial. An example of this complex type of structure is illustrated by *G. nigra* Redhead (Fig. 4b). The phrase 'germination compartment' (e.g., Hall 1984) has been used for this structure, but Koske *et al.* (1983) and Koske & Walker (1985) termed it a 'germination shield'. Figures 5 & 6 illustrate the 'compartment-like' features which prompted the use of the former term. We prefer the use of the latter phrase because it is descriptive of both form and function, rather than merely of the form viewed in optical section (Hall 1977). Only one germination shield is formed in each spore, though it may produce more than one germ tube.

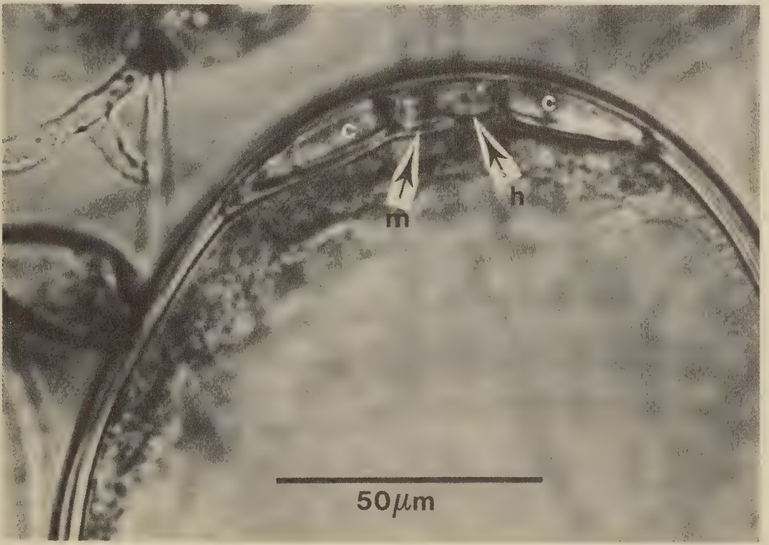


Fig. 5: Light micrograph of an optical section through the germination shield of *Gigaspora calospora*. The hole created at initiation of the shield can be seen (h), and the two lobes which form the compartments (c) from which germ tubes may emerge are delimited by the folded membranous wall (m). The fold in the membranous wall is out of focus on the right of the hole.

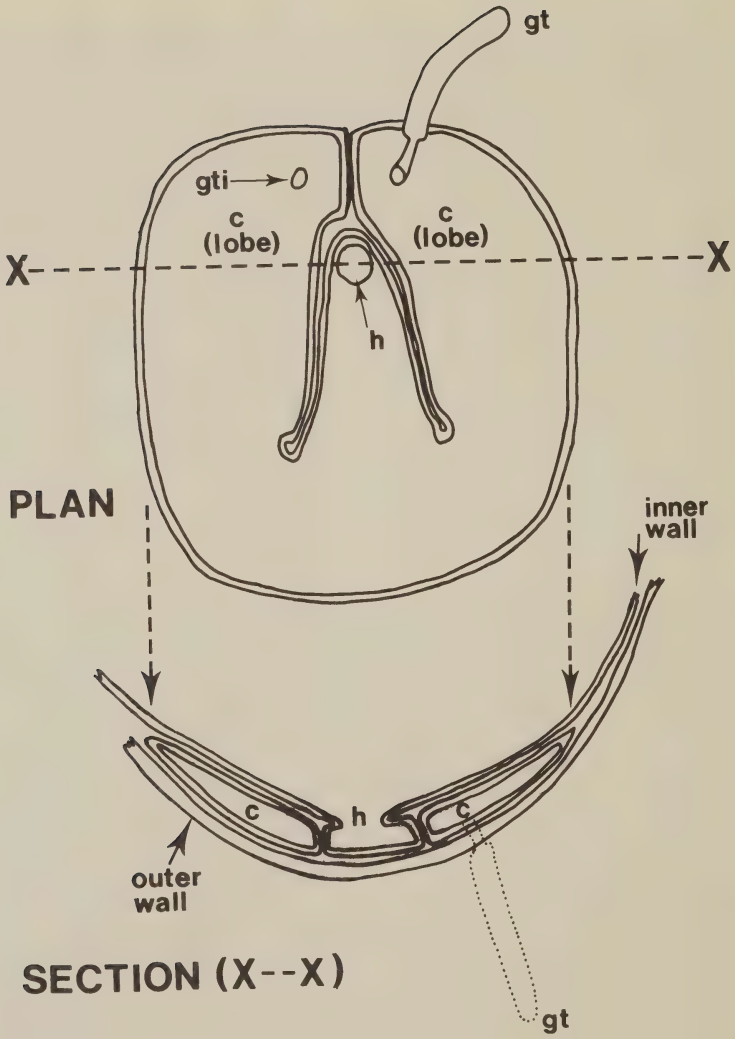

gt
gti
c
(lobe)
c
(lobe)
X
X
h
PLAN
inner wall
c
h
c
outer wall
SECTION (X--X)
gt

Fig. 6: Diagrammatic representation of the simplest form of germination shield (as in Figs. 4a & 5) drawn as a plan view and a cross section through the line X-X which passes through the hole (h) that appears at the initiation of shield formation. This form of shield has only two lobes each of which creates a compartment (c) with a germ tube initial (gti). A germ tube is shown emerging from the lobe on the right (gt).

The original descriptions of *G. calospora* and *G. gigantea* did not distinguish between their germination modes, indicating merely that both species germinated directly through the spore wall near the attachment. This was discussed by Hall and Abbott (1984) who, from examination of the type material of *G. calospora*, showed that its germination was by means of a germination shield.

Germination shields may have taxonomic value at species level in the future and they should be described and illustrated whenever possible in species descriptions.

Auxiliary cells

When the first species of the group were formally described (Nicolson & Gerdemann 1968) it was recognised that auxiliary cells were of two forms (Fig. 7). Both begin as smooth sacs (Fig. 7a), but as they mature, they develop different kinds of ornamentation. The first type, represented by *G. gigantea*, is decorated by echinulations or narrow papillae, which may be cut off from the main body of the sac by septa (Fig. 7b). The other form, of which *G. calospora* is typical, has auxiliary cells that become knobby due to the formation of much broader, blunt projections or very broad, relatively low papillae (Fig. 7c). Although there may be some minor differences among species (Trappe 1982), such differences are merely variations of these two basic forms. Examination of the literature and of specimens of most of the currently described species indicates that each has exclusively one or other of these types. Though Nicolson & Gerdemann (1968) indicated that the auxiliary cells of *G. heterogama* were smooth, they are in fact knobby (Koske & Walker 1985), and it is probable that the former authors were observing immature cells. Regardless of minor variations, therefore, these will be termed 'echinulate' and 'knobby' auxiliary cells (Figs. 7 & 8). The species with spores that have only a single wall group and that germinate by direct germination have the former, while the species with membranous inner walls that germinate by means of a germination shield have the latter. The shape

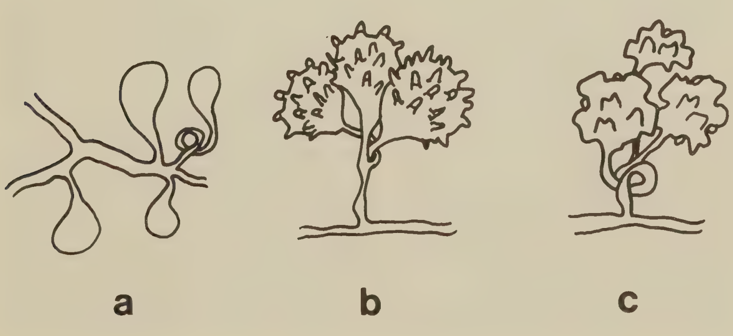


Fig. 7: Drawings of auxiliary cells in *Gigaspora sensu lato*.
a) Immature auxiliary cells before acquisition of ornamentation.
b) Echinulate auxiliary cells typical of the *G. gigantea* group within the genus.
c) Knobby auxiliary cells, typical of the *G. calospora* group.

of auxiliary cells has been thought to have some taxonomic value at the specific level (Trappe 1982), but Koske & Walker (1985) give this character little weight because of the large variation within, and the similarities among species.

Summary of characteristics separating the two groupings

The genus *Gigaspora* Gerd. & Trappe can be divided into two distinctive genera, primarily on the basis of germination characteristics, but also of spore wall structure and morphology of auxiliary cells. In one group, for which the generic name *Gigaspora* will be retained in accordance with the International Code of Botanical Nomenclature (Article 52), germination is by egress of a germ tube directly through the outer spore wall, spores do not possess inner wall groups of (flexible)

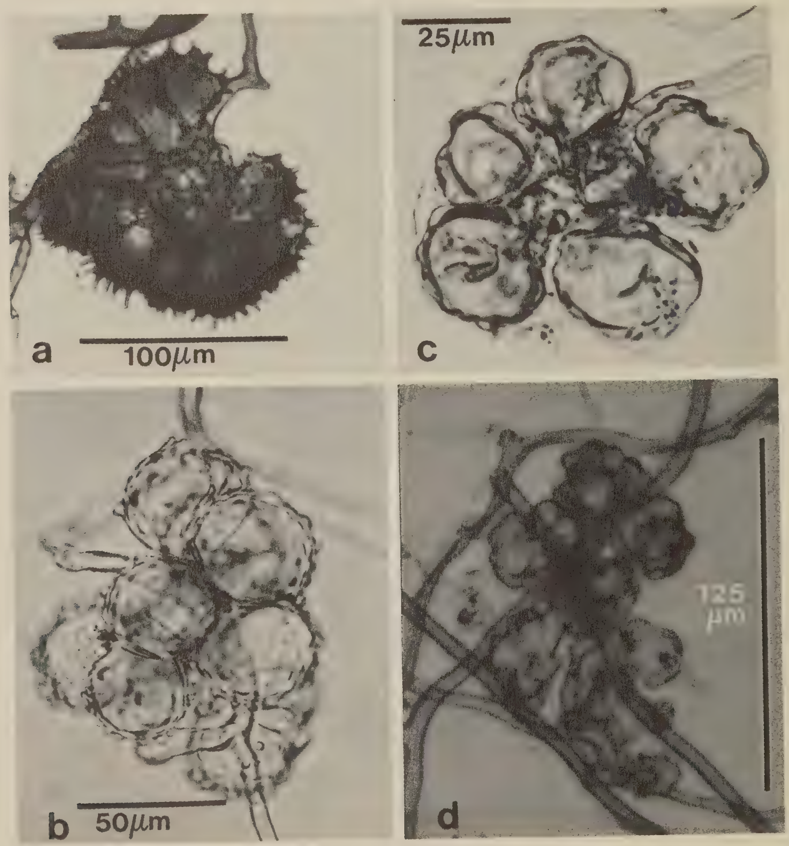


Fig. 8: The two types of auxiliary cells in *Gigaspora sensu lato.*
a & b) Echinulate auxiliary cells from an undescribed species, and *G. margarita*, respectively.
c & d) Knobby auxiliary cells from an undescribed species and *G. heterogama*, respectively.

membranous or coriaceous walls, and auxiliary cells are echinulate. This group is exemplified by the species *Gigaspora gigantea*. The second group, represented by *Gigaspora calospora*, has spores which germinate by means of a germination shield formed in an inner wall group of membranous or coriaceous walls. Auxiliary cells of these fungi are knobby. Many species in this group have ornamented outer walls (Koske & Walker 1985), whereas no described species in the first group does.

Auxiliary cells are delicate and not always easy to find, except from pot cultures. Germination shields form at a late stage in the development of the spore, may not be present in all specimens, and may be very difficult to see on species with hyaline spores. Nevertheless, the presence or absence of an inner wall group with at least one flexible wall can always readily be detected, and a species can be placed in its group on this characteristic alone. There thus will be no difficulty in identifying the appropriate grouping for a species. The *G. calospora* grouping is herein given separate generic status as *Scutellospora* gen. nov.

GIGASPORA Gerdemann & Trappe (*Mycologia Memoir No. 5*, p. 25, 1974) emend. Walker & Sanders

Spores produced singly in soil, large variable in shape, usually globose or subglobose, but often ovoid, obovoid, pyriform, or irregular, especially when constrained during formation, borne on a bulbous suspensor-like cell, usually with a narrow hypha extending from one or more peg-like projections towards the spore. Spore wall structure of a single wall group, lacking flexible (membranous or coriaceous) walls. One or more germ tubes produced directly through the spore wall near the base. Thin-walled, echinulate or finely papillate auxiliary cells borne in soil, on straight or coiled hyphae, formed singly or in clusters. Forming endomycorrhizas with arbuscules and hyphal coils, but without vesicles.

SPECIES INCLUDED

Gigaspora gigantea (Nicol. & Gerd.) Gerd. & Trappe, *Mycologia Memoir No. 5*, pp. 29-30. 1974.

≡ *Endogone gigantea* Nicol. & Gerd., *Mycologia* **60**: 321. 1968.

Gigaspora margarita Becker & Hall, *Mycotaxon* **4**:1-2. 1976.

Gigaspora candida Bhattacharjee *et al.*, *Transactions of the British Mycological Society* **78**:184. 1982.

Gigaspora decipiens Hall & Abbott, *Transactions of the British Mycological Society* **83**:204. 1984.

Gigaspora rosea Nicol. & Schenck, *Mycologia* **71**:190. 1979.

Gigaspora albida Schenck & Smith, *Mycologia* **74**:85. 1982.

SCUTELLOSPORA Walker & Sanders, gen. nov.

Sporae in solo singulariter productae, terminaliter in cellula bulbosa suspensoriformi portatae, plerumque hypha angusta e cellula suspensoriformi ad sporam extensa. Paries sporae stratosus, stratis in turmis duabus vel ultra, turma interiore stratorum flexibilium composita. Scutum germinationis prope basim sporae in vel inter stratis flexibilibus interioribus formatum, tubo germinationi uno vel ultra ex scuto germinationi formato. Cellulae auxiliares nodosae singulariter vel fasciculatae in solo portatae. Fungus endomycorrhizas cum arbusculis et hyphis spiralibus sed sine vesiculis formans. Typus - *Scutellospora calospora* (Nicolson & Gerdemann) Walker & Sanders.

Spores produced singly in soil (or rarely in cortical cells of roots), large, variable in shape, usually globose or subglobose, but often ovoid, obovoid, pyriform, or irregular especially when constrained during formation; borne on a bulbous suspensor-like cell, usually with a narrow hypha extending from one or more peg-like projections towards the spore. Spore wall structure of at least two wall groups, with one or more flexible membranous or coriaceous walls in the inner group or groups. Germination by means of one or more germ tubes produced near the spore base from a germination shield formed upon or within a flexible inner wall. Thin-walled, knobby or broadly papillate auxiliary cells borne in soil, on straight or coiled hyphae, formed singly or in clusters.

Forming endomycorrhizas with arbuscules and hyphal coils, but without vesicles.

ETYMOLOGY: Latin, *scutellum*, small shield and *spora*, spore; referring to the production of germination shields in spores of members of the genus.

SPECIES INCLUDED

Scutellospora calospora (Nicol. & Gerd.) Walker & Sanders, comb. nov.

≡*Endogone calospora* Nicol. & Gerd., *Mycologia* **60**:322. 1968.

≡*Gigaspora calospora* (Nicol. & Gerd.) Gerd. & Trappe, *Mycologia Memoir No. 5*. pp. 28-29. 1974.

Scutellospora heterogama (Nicol. & Gerd.) Walker & Sanders, comb. nov.

≡*Endogone heterogama* Nicol. & Gerd., *Mycologia* **60**: 319-320. 1968.

≡ *Gigaspora heterogama* (Nicol. & Gerd.) Gerd. & Trappe, *Mycologia Memoir No. 5*. p. 31. 1974.

Scutellospora alborosea (Ferr. & Herr.) Walker & Sanders, comb. nov.

≡ *Gigaspora alborosea* Ferr. & Herr., *Rev. Jardin Bot. Nac., Habana* **1**:55-57. 1981.

Scutellospora minuta (Ferr. & Herr.) Walker & Sanders, comb. nov.

≡ *Gigaspora minuta* Ferr. & Herr., *Rev. Jardin Bot. Nac., Habana* **1**:53-54. 1981.

Scutellospora auriglobā (Hall) Walker & Sanders, comb. nov.

≡ *Gigaspora auriglobā* Hall, *Transactions of the British Mycological Society* **68**:351. 1977.

Scutellospora savannicola (Herr. & Ferr.) Walker & Sanders, comb. nov.

≡ *Gigaspora savannicola* Herr. & Ferr. in Ferr. & Herr., *Rev. Jardin Bot. Nac., Habana* **1**:57-60. 1981.

Scutellospora tricalypta (Herr. & Ferr.) Walker & Sanders, comb. nov.

≡ *Gigaspora tricalypta* Herr. & Ferr. in Ferr. & Herr., *Rev. Jardin Bot. Nac., Habana* **1**:49-51. 1981.

Scutellospora erythropa (Koske & Walker) Walker & Sanders, comb. nov.

≡ *Gigaspora erythropa* Koske & Walker, *Mycologia* **76**: 250-252. 1984.

Scutellospora dipapillosa (Walker & Koske) Walker & Sanders, comb. nov.

≡ *Gigaspora dipapillosa* Walker & Koske in Koske & Walker, *Mycologia* **77**:709-710. 1985.

Scutellospora persica (Koske & Walker) Walker & Sanders, comb. nov.

≡ *Gigaspora persica* Koske & Walker, *Mycologia* **77**:708-709. 1985.

Scutellospora verrucosa (Koske & Walker) Walker & Sanders, comb. nov.

≡ *Gigaspora verrucosa* Koske & Walker, *Mycologia* **77**:705-706. 1985.

Scutellospora reticulata (Koske, Miller & Walker) Walker & Sanders, comb. nov.

≡ *Gigaspora reticulata* Koske, Miller & Walker, *Mycotaxon* **16**:429-433. 1983.

Scutellospora gregaria (Schenck & Nicol.) Walker & Sanders, comb. nov.

≡ *Gigaspora gregaria* Schenck & Nicol in Nicol. & Schenck, *Mycologia* **71**:185-186. 1979.

Scutellospora pellucida (Nicol. & Schenck) Walker & Sanders, comb. nov.

≡ *Gigaspora pellucida* Nicol. & Schenck, *Mycologia* **71**:189-190. 1979.

Scutellospora nigra (Redhead) Walker & Sanders, comb. nov.

≡ *Gigaspora nigra* Redhead in Nicol & Schenck, *Mycologia* **71**:187-188. 1979.

Scutellospora gilmorei (Trappe & Gerd.) Walker & Sanders, comb. nov.

≡ *Gigaspora gilmorei* Trappe & Gerd. in Gerd. & Trappe, *Mycologia Memoir No. 5*. pp. 27-28. 1974.

Scutellospora coralloidea (Trappe, Gerd. & Ho) Walker & Sanders, comb. nov.

≡ *Gigaspora coralloidea* Trappe, Gerd. & Ho in Gerd. & Trappe, *Mycologia Memoir No. 5*. pp. 30-31. 1974.

ACKNOWLEDGEMENTS

We are grateful to Dr. R. E. Koske, University of Rhode Island, and Dr. N. C. Schenck, University of Florida for kindly reviewing the manuscript and for their helpful comments, and Dr. Bud Uecker, Mycology Laboratory, Beltsville, Maryland for preparing the Latin diagnosis. We also thank Colin McEvoy, Forestry Commission for help in preparing the plates.

REFERENCES

Becker, W. N. and Hall, I. R. 1976. *Gigaspora margarita*, a new species in the Endogonaceae. *Mycotaxon* **4**:155-160.

Berch, S. M. and Fortin, J. A. 1982. Germination of zygospores of *Endogone incrassata*. *Mycologia* **74**:861-864.

Bhattacharjee, K. G., Mukerji, K. G., Tewari, J. P. and Skoropad, W. P. 1982. Structure and hyperparasitism of a new species of *Gigaspora*. *Transactions of the British Mycological Society* **78**:184-188.

Ferrer, R. L., and Herrera, R. A. 1981. El genero *Gigaspora* Gerdemann et Trappe (Endogonaceae) en Cuba. *Rev. Jardin Bot. Nacional, Habana* **1**(1):43-66.

Gerdemann, J. W. and Trappe, J. M. 1974. The Endogonaceae in the Pacific Northwest. *Mycologia Memoir No. 5.* 76 pp.

Gibson, J. L. 1985. *Morphology, cytology and ultrastructure of selected species of Endogonaceae (Endogonales: Zygomycetes).* Unpublished PhD dissertation, University of Florida, Gainesville, Florida. 166 pp.

Hall, I. R. 1977. Species and mycorrhizal infections of New Zealand Endogonaceae. *Transactions of the British Mycological Society*. **68**:341-356.

Hall, I. R. 1984. Taxonomy of VA mycorrhizal fungi. pp. 57-94. In: *VA Mycorrhiza*. Ed. by C. LL. Powel and D. J. Bagyaraj. CRC Press, Florida.

Hall, I. R. and Abbott, L. K. 1984. Some Endogonaceae from South Western Australia. *Transactions of the British Mycological Society*, **83**:203-208.

Koske, R. E., Miller, D. D. and Walker, C. 1983. *Gigaspora reticulata*: a newly described endomycorrhizal fungus from New England. *Mycotaxon* **16**:429-435.

Koske, R. E. and Walker, C. 1984. *Gigaspora erythropa*, a new species forming arbuscular mycorrhizae. *Mycologia* **76**:250-255.

Koske, R. E. and Walker, C. 1985. Species of *Gigaspora* (Endogonaceae) with roughened outer walls. *Mycologia* **77**:702-720.

Nicolson, T. H. and Gerdemann, J. W. 1968. Mycorrhizal *Endogone* species. *Mycologia* **60**:313-325.

Nicolson, T. H. and Schenck, N. C. 1979. Endogonaceous mycorrhizal endophytes in Florida. *Mycologia* **71**:178-198.

Schenck, N. C. and Smith, G. S. 1982. Additional new and unreported species of mycorrhizal fungi (Endogonaceae) from Florida. *Mycologia* **74**:77-92.

Sward, R. J. 1981. The structure of the spores of *Gigaspora margarita*. II. Germ-tube emergence and growth. *New Phytologist* **88**:667-673.

Trappe, J. M. 1982. Synoptic keys to the genera and species of zygomycetous mycorrhizal fungi. *Phytopathology* **72**:1102-1108.

Trappe, J. M. and Schenck, N. C. 1982. Taxonomy of the fungi forming endomycorrhizae. A. Vesicular-arbuscular mycorrhizal fungi (Endogonales). Pp. 1-9. In: *Methods and Principles of Mycorrhizal Research*. Ed. by N. C. Schenck. The American Phytopathological Society, St. Paul, Minnesota.

Walker, C. 1983. Taxonomic concepts in the Endogonaceae: spore wall characteristics in species descriptions. *Mycotaxon* **18**:443-455.

Walker, C. 1985. Taxonomy of the Endogonaceae. Pp. 193-199. In: *Proceedings of the 6th North American Conference on Mycorrhizae*. Ed. by R. Molina. Forest Research Laboratory, Corvallis, Oregon.

Walker, C. 1986. Taxonomic concepts in the Endogonaceae. II. A fifth morphological wall type in endogonaceous spores. *Mycotaxon* **25**:95-99.

Walker, C., Mize, C. W. and McNabb, H. S. Jr. 1982. Populations of endogonaceous fungi at two locations in central Iowa. *Canadian Journal of Botany* **60**:2518-2529.

Walker, C. and Sanders, F. E. 1985. Germination shields in the genus *Gigaspora*. p. 433. In: *Proceedings of the 6th North American Conference on Mycorrhizae.* Ed. by R. Molina. Forest Research Laboratory, Corvallis, Oregon.

MYCOTAXON

Vol. XXVII, pp. 183-192 October-December 1986

FIVE NEW SPECIES OF *PARMELIA* (LICHENES, PARMELIACEAE) FROM SOUTHERN AFRICA.

FRANKLIN A. BRUSSE.

Botanical Research Institute,
Private Bag X101, PRETORIA,
SOUTH AFRICA.

ABSTRACT

Five new species of *Parmelia* (Lichenes, Parmeliaceae) are described from southern Africa. They are: *Parmelia eximia, P. fausta, P. insignis, P. inuncta*, and *P. pudens*. Their chemistries and affinities are discussed.

PARMELIA EXIMIA Brusse, *sp. nov.*

Thallus foliosus, saxicola, usque ad 4 cm diametro. *Lobi* elongati, circa 1.5 mm lati, 120–200 μm crassi. *Thallus superne* viridis, nitidus, emaculatus, isidiis sorediisque nullis. *Cortex superior* 15 μm crassus. *Stratum gonidiale* 30–50 μm crassum, algis *Trebouxiis*, 4.5–18 μm diametris. *Medulla* albida, 80–120 μm crassa. *Cortex inferior* circa 10 μm crassus. *Thallus inferne* pallidus. *Rhizinae* 30–60 μm crassae. *Apothecia* usque ad 5 mm diametris. *Hypothecium* 35–40 μm crassum. *Subhymenium* 10–15 μm crassum. *Hymenium* 40–60 μm altum, J+ caeruleum. *Asci* clavati, cum tholis J+ caeruleis (fig. 1), poricidales. *Ascosporae* octonae, subsphaericae, 7.0–7.5 x 8.0–8.5 μm. *Pycnidia* globosa, circa 150 μm diametris. *Pycnidiosporae* bacillares, hyalinae, 6–8.5 x 1 μm. *Thallus* acidum usnicum et materias ignotas continens.

TYPUS: SOUTH AFRICA, Cape Province, 65 km WNW of Willowmore, Kouka river basin, 1 km SE of Rietkuil farmstead, on shale outcrops on gentle S slope, alt. 810 m, *F. Brusse 4840*, 5.ii.1986, (PRE, holo-; BM, COLO, LD, US, iso-), fig. 6.

Thallus foliose, saxicolous, up to 4 cm diam. *Lobes* elongate, about 1.5 mm broad, 120–200 μm thick. *Upper surface* green, nitid, emaculate, isidia and soredia absent. *Upper cortex* 15 μm thick. *Algal layer* 30–50 μm thick, algae *Trebouxia*, 4.5–18 μm diam. *Medulla* whitish, 80–120 μm thick. *Lower cortex* around 10 μm thick. *Lower surface* pale, rhizinate. *Rhizines* 30–60 μm thick. *Apothecia* up to 5 mm diam. *Hypothecium* 35–45 μm thick. *Subhymenium* 10–15 μm thick. *Hymenium* 40–60 μm high, J+ blue. *Asci* clavate, tholus J+ blue (fig. 1), poricidal with some extension of the ascus, 8 spored. *Ascospores* subsphaerical, 7.0–7.5 x 8.0–8.5 μm. *Pycnidia* globose, about 150 μm diam. *Pycnidiospores* hyaline rods (with 2 subterminal swellings each), 6–8.5 x 1 μm. *Chemistry*: Usnic acid in the upper cortex, and six unknowns in the medulla (FB–1 to FB–6, table 1).

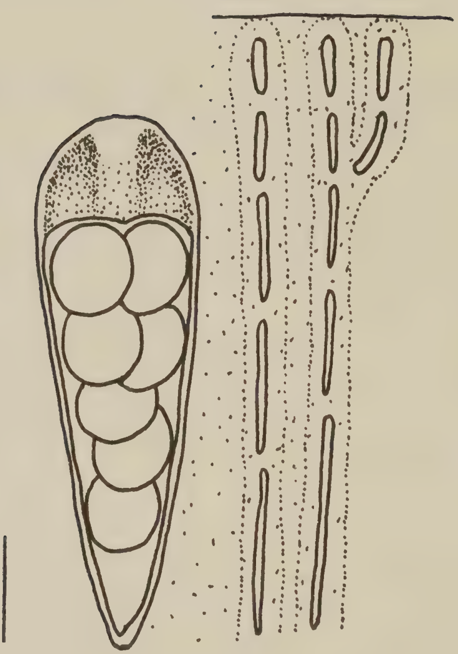


FIG. 1. *Parmelia eximia* Brusse, ascus and paraphyses. *F. Brusse 4840*, holotype. Bar = 10 μm.

Parmelia eximia is here assigned to *Xanthoparmelia*, but is unique in this section in possessing subsphaerical ascospores and an unusual chemistry. The subsphaerical ascospores are very similar to those of *Parmelia sphaerospora* Nyl., but the latter is a larger corticolous species of humid areas, containing atranorin in the upper cortex and a yellow pigment in the medulla, with or without stictic or hypostictic acids and associated compounds, or sometimes gyrophoric acid (Hale, 1976). The unknown substances in *P. eximia* appear to be depsidones, as several spots remain unchanged on subjection to acid hydrolysis. The Rf values of these substances are listed in table 1. Thin layer chromatography was carried out on the acetone extract of cleaned lobes of these lichens, in accordance with the method of Culberson (1972), with the modified solvent B, using *tert.*-butyl methyl ether instead of diethyl ether (Culberson & Johnson, 1982).

Thus far, this unique *Xanthoparmelia* has only been found in the Kommandokraal area of the Kouka river basin, some 60 km WNW of Willowmore, in the southern Cape Province.

SOUTH AFRICA, Cape Province – **3322** (Oudtshoorn): 62 km WNW of Willowmore (2 km WNW of Vlieëkraal farmstead), on sandstone outcrops on gentle S slope, altitude 810 m (–BB), *F. Brusse 4844*, 5.ii.1986 (PRE, COLO, LD).

PARMELIA FAUSTA Brusse, *sp. nov.*

Thallus minute foliosus, saxicola, usque ad 4 cm diametro.*Lobi* sublineares, 0.2–1.0 mm lati, 110–150 µm crassi, *Thallus superne* cinereus, nitidus, emaculatus, isidiis sorediisque nullis. *Cortex superior* 15–20 µm crassus. *Stratum gonidiale* 30–45 µm crassum, algis *Trebouxiis* 5–15 µm diametris. *Medulla* aurantiaca, 45–90 µm crassa. *Cortex inferior* 15–20 µm crassus. *Thallus inferne* piceus. *Rhizinae* simplices, 90–100 µm crassae. *Apothecia* usque ad 1.2 mm diametris. *Hypothecium* 30–45 µm crassum. *Subhymenium* 35 µm crassum. *Hymenium* 70 µm altum, J+ caeruleum. *Asci* clavati, cum tholis J+ caeruleis (fig. 2), poricidales. *Ascosporae* octonae, ellipsoideae, 10–12 x 6.5–7.5 µm. *Pycnidia* ignota. *Thallus* atranorinum, acidum lecanoricum, et duo pigmenta ignota (ut in *Parmelia schenckiana* Mull. Arg.) continens.

TYPUS: SOUTH AFRICA, Cape Province, 19 km S of Prince Albert, summit of Swartberg Pass, wind blown SE gulleys, on S faces of TMS rock near the ground, altitude 1650 m, *F. Brusse 4891*, 7.ii.1986 (PRE, holo-; BM, COLO, LD, MEL, US, iso-), fig. 3.

Thallus minutely foliose, saxicole, up to 4 cm across. *Lobes* sublinear, 0.2–1.0 mm broad, 110–150 µm thick. *Upper surface* grey, nitid, emaculate, not isidiate and not sorediate. *Upper cortex* 15–20 µm thick. *Algal layer* 30–45 µm thick, algae *Trebouxia*, 5–15 µm diam. *Medulla* orange, 45–90 µm thick. *Lower cortex* 15–20 µm thick. *Lower surface* black. *Rhizines* simple, 90–100 µm thick. *Apothecia* up to 1.2 mm across. *Hypothecium* 30–45 µm thick. *Subhymenium* 35 µm thick. *Hymenium* 70 µm high, J+ blue. *Asci* clavate, with J+ blue tholus (fig. 2), poricidal with extension of the apex. *Ascospores* eight, ellipsoid, 10–12 x 6.5–7.5 µm. *Pycnidia* not found. *Chemistry*: Atranorin in the upper cortex, lecanoric acid and 2 pigments (as in *P. schenckiana* Mull. Arg.) in the medulla.

This lichen is one of a group of very narrow-lobed Parmelias which occur in the mountains of the southern Cape. At higher altitudes, these mountains are covered with a good proportion of shrubs with sclerotized, needle-shaped leaves; this type of vegetation is referred to as *fynbos*. The *Parmelia* flora of these mountains seems to have developed the same way, with a large number of narrow-lobed species present. Even species which have a wider distribution here produce narrower lobes and a more pulvinate growth habit at these high altitudes. In the case of the Parmelias, this is almost certainly a response to improved mist interception, and is to some extent true for the higher plant cover as well.

Parmelia fausta resembles *P. astricta* as well as the newly described *P. insignis*, but the most conspicuous difference is the chemistry. *P. molybdiza* Nyl. is also black below and contains lecanoric acid, but this is a broader-lobed lichen without any pigments in the medulla.

At present, this new lichen is known only from the type locality, the Swartberg range at high altitudes.

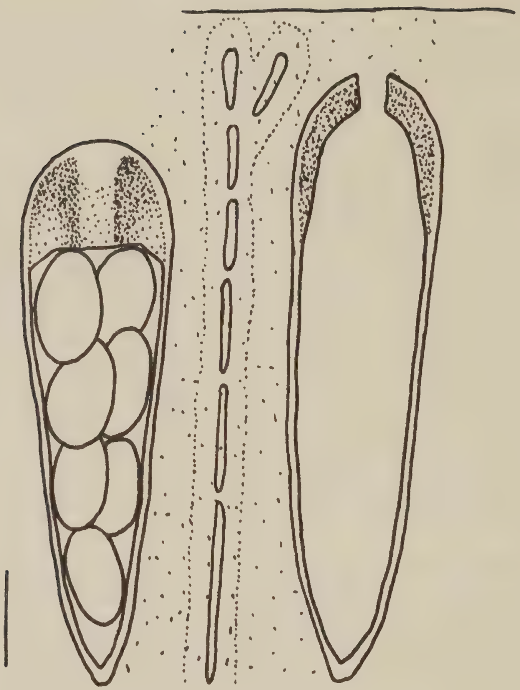


FIG. 2. *Parmelia fausta* Brusse, ascus and paraphyses. *F. Brusse 4891*, holotype. Bar = 10 μm.

PARMELIA INSIGNIS Brusse, *sp. nov.*

Thallus minute, foliosus, saxicola, usque ad 3 cm diametro. *Lobi* sublineares, 0.1–0.8 mm lati, 100–170 μm crassi. *Thallus superne* cinereus, nitidus, emaculatus, isidiis sorediisque nullis. *Cortex superior* 10–17 μm crassus. *Stratum gonidiale* 25–40 μm crassum, algis *Trebouxiis*, 6–17 μm diametris. *Medulla* alba, 50–90 μm crassa. *Cortex inferior* 5–20 μm crassus. *Thallus inferne* piceus. *Rhizinae* simplices, 50–80 μm crassae. *Apothecia* usque ad 0.8 mm diametris. *Hypothecium* 15–25 μm crassum. *Subhymenium* 10 μm crassum. *Hymenium* 60 μm altum, J+ caeruleum. *Asci* clavati, cum tholis J+ caeruleis. *Ascosporae* non visae. *Pycnidia* ignota. *Thallus* atranorinum et materias ignotas continens.

TYPUS: SOUTH AFRICA, Cape Province, Robinsons Pass between Mossel Bay and Oudtshoorn, on TMS outcrops on steep SW slope of Ruitersberg, alt. 790 m, *F. Brusse 4801*, 4.ii.1986 (PRE, holo-; BM, COLO, LD, MEL, US, iso-), fig. 4.

Thallus, minutely foliose, saxicole, up to 3 cm across. *Lobes* sublinear, 0.1–0.8 mm broad, 100–170 μm thick. *Upper surface* grey, nitid, without isidia, soredia or maculae.

Upper cortex 10–17 μm thick. *Algal layer* 25–40 μm thick, algae *Trebouxia*, 6–17 μm diam. *Medulla* white, 50–90 μm thick. *Lower cortex* 5–20 μm thick. *Lower surface* black. *Rhizines* simple, 50–80 μm thick. *Apothecia* up to 0.8 mm across. *Hypothecium* 15–25 μm thick. *Subhymenium* 10 μm thick. *Hymenium* 60 μm high, J+ blue. *Asci* clavate, tholus J+ blue (only spent asci present). *Ascospores* not seen. *Pycnidia* not found. *Chemistry*: Atranorin and major amounts of two unidentified substances (probably *meta*-depsides), and traces of several others.

Parmelia insignis is another *fynbos* lichen with sublinear, narrow lobes, and is readily distinguished from its similar looking compatriots by its chemistry. Two major medullary substances are present which are almost certainly *meta*-depsides. These substances could not be positively identified with any of the well known *meta*-depsides, but there are a number of recently described *meta*-depsides, for which no microcrystal and hydrolysis data, necessary for the rapid confirmation of the identity of these substances, are available (Chester & Elix, 1978). The substances have consequently been given code names, and **insig.-1** is always the major substance (See Table 1 for R_f values). **Insig.-2** is present in smaller amounts or absent. **Insig.-3** may be a terpene, and is mostly present in trace amounts. Up to 6 other traces (best seen in solvent B) occur below **insig.-3**, and resemble it in spot colour and shape. This probably represents a series of closely related terpenes, some of which may be artifacts of the TLC procedure.

At present this lichen is known only from the type locality, the SW slopes of Ruitersberg, between Mossel Bay and Oudtshoorn, at the western end of the Outeniqua Mountains.

PARMELIA INUNCTA Brusse, *sp. nov.*

Thallus minute foliosus, saxicola, usque ad 3 cm diametro. *Lobi* sublineares, 0.2–0.7 mm lati, 100–120 μm crassi. *Thallus superne* viridis, nitidus, emaculatus, isidiis sorediisque nullis. *Cortex superior* 15–20 μm crassus. *Stratum gonidiale* 25–35 μm crassum, algis *Trebouxiis*, 5–16 μm diametris. *Medulla* alba, 35–50 μm crassa. *Cortex inferior* 12–15 μm crassus. *Thallus inferne* piceus. *Rhizinae* 45–65 μm crassae. *Apothecia* usque ad 0.8 mm diametris. *Hymenium* non visum. *Pycnidia* ignota. *Thallus* acidum usnicum et acida aliphatica ignota (ut in *Parmelia subdecipienti* Vain. ex Lynge) continens.

TYPUS: SOUTH AFRICA, Cape Province, Robinsons Pass between Mossel Bay and Oudtshoorn, on TMS on steep SW slope of Ruitersberg, alt. 790 m, *F. Brusse 4810*, 4.ii.1986 (PRE, holo-; BM, LD, iso-), fig. 5.

Thallus minutely foliose, saxicolous, up to 3 cm across. *Lobes* sublinear, 0.2–0.7 mm broad, 100–120 μm thick. *Upper surface* green, nitid, without maculae, isidia or soredia. *Upper cortex* 15–20 μm thick. *Algal layer* 25–35 μm thick, algae *Trebouxia*, 5–16 μm diam. *Medulla* white, 35–50 μm thick. *Lower cortex* 12–15 μm thick. *Lower surface* black. *Rhizines* 45–65 μm thick. *Apothecia* up to 0.8 mm across. *Hymenium* not seen (the available material seemed to have the hymenia grazed off). *Pycnidia* unknown. *Chemistry*: Usnic acid in the upper cortex, and unknown aliphatic acids (as in *P. subdecipiens* Vain. ex Lynge) in the medulla.

This is the second small *Xanthoparmelia* containing the ‘subdecipiens fatty acids’, the other, *Parmelia unctula* Brusse (1984), is a more normal *Xanthoparmelia* with elongate lobes, and is pale below. These fatty acids do not appear to belong to the constipatic acid series (Chester & Elix, 1979), although I have not personally worked with this group of fatty acids. Brusse (1980) synonomized *Parmelia irregularis* (Gyeln.) Kurok. with *P. subdecipiens* Vain. ex Lynge. *P. irregularis*, therefore contains the 'subdecipiens fatty acids'. Kurokowa & Filson (1975) depicted a chromatogram on which the extract of *P. irregularis* had been run together with those of several other Australian Parmelias containing the constipatic acid group of fatty acids, and they are shown to be different. It thus seems certain that the 'subdecipiens fatty acids' so common in southern African *Xanthoparmeliae*, are not the same as the constipatic acid series, so common in Australian *Xanthoparmeliae*.

At present this species is known only from the type collection, from Robinsons Pass between Mossel Bay and Oudtshoorn.

PARMELIA PUDENS Brusse, *sp. nov.*

Thallus minute foliosus, saxicola, usque ad 3 cm diametro. *Lobi* sublineares, 0.1–0.5 mm lati, circa 100 μm crassi. *Thallus superne* cinereus, nitidus, emaculatus, sorediis isidiisque nullis. *Cortex superior* 12–14 μm crassus. *Stratum gonidiale* 15–25 μm crassum, algis *Trebouxiis* 4.5–17 μm diametris. *Medulla* albida, 40–55 μm crassa. *Cortex inferior* 10 μm crassus. *Thallus inferne* piceus. *Rhizinae* simplices, 40–55 μm crassae. *Apothecia* et *pycnidia* ignota. *Thallus* atranorinum et acidum salazinicum continens.

TYPUS: SOUTH AFRICA, Cape Province, Robinsons Pass between Mossel Bay and Oudtshoorn, on TMS on steep SW slope of Ruitersberg, alt. 790 m, *F. Brusse 4792*, 4.ii.1986 (PRE, holo-), fig. 7.

Thallus minutely foliose, saxicolous, up to 3 cm across. *Lobes* sublinear, 0.1–0.5 mm broad, around 100 μm thick. *Upper surface* grey, nitid, without maculae, soredia or isidia. *Upper cortex* 12–14 μm thick. *Algal layer* 15–25 μm thick, algae *Trebouxia*, 4.5–17 μm diam. *Medulla* whitish (red in moribund lobes), 40–55 μm thick. *Lower cortex* 10 μm thick. *Lower surface* black. *Rhizines* simple, 40–55 μm thick. *Apothecia* and *pycnidia* not seen. *Chemistry*: Atranorin, salazinic acid and a smaller amount of norstictic acid.

Parmelia pudens resembles the Australian species *P. lithophiloides* Kurok. (1985) in character combinations, but the latter has lobes up to 2 mm broad, and is much coarser than *P. pudens*, despite being small itself. *P. lithophiloides* also has constipatic acid in the medulla while *P. pudens* is without fatty acids.

This is another *fynbos* lichen, occurring at higher altitudes in the southern Cape mountains. At present this species is known only from the type locality, SW slope of Ruitersberg at the western end of the Outeniqua mountains, between Mossel Bay and Oudtshoorn.

ACKNOWLEDGEMENTS

The author is grateful to the South African Department of Agriculture and Water Supply for financial support. Thanks go to Mrs A.J. Romanowski for the photography and to the typists. Thanks are also extended to Mr. P.W. James for reviewing the manuscript.

TABLE 1.—R_f Characteristics of the Unknown Substances (Culberson, 1972; Culberson & Johnson, 1982)

LICHEN SUBSTANCE	R_f CLASS			R_f VALUE × 100			COLOUR WITH H_2SO_4 + HEAT	UV CHARACTERISTICS	
	A	B	C	A	B	C		366 nm	254 nm
FB–3	2	2	1	7/48,77(60)	15/40,79(58)	2/36,67(48)	brownish	pale or –	Quench
FB–2	2	3	2	12/48,77(60)	24/40,79(58)	11/36,67(48)	brownish	pale or –	Quench
FB–1	2–3	4	4	25/48,77(60)	36/40,79(58)	34/36,67(48)	pale brownish	white	Quench
FB–4	3	4–5	2–3	29/48,77(60)	43/40,79(58)	19/36,67(48)	brownish	pale or –	Quench
FB–5	3	5	3	37/48,77(60)	49/40,79(58)	26/36,67(48)	brownish	pale or –	Quench
FB–6	4	5–6	5–6	47/48,77(60)	58/40,79(58)	51/36,67(48)	brownish	pale or –	Quench
insig.–1	4	6	6	51/48,77(60)	64/40,79(58)	52/36,67(48)	pinkish, pale yellow then yellow-brown	white	Quench
insig.–2	4	6	6	51/48,77(60)	69/40,78(58)	52/36,67(48)	pinkish, pale yellow then yellow-brown	–	Quench
insig.–3	3	5	5	43/48,77(60)	49/40,79(58)	44/36,67(48)	yellow-orange	–	Quench

LITERATURE CITED

BRUSSE, F. 1980. *A taxonomic and geographic study of the genus* Xanthoparmelia *in the Karoo*. M.Sc. dissertation, University of the Witwatersrand, Johannesburg, 305 pp.

BRUSSE, F. 1984. New species and combinations in *Parmelia* (Lichenes) from southern Africa. *Bothalia* **15** (1 & 2): 315–321.

CHESTER, D.O. & ELIX, J.A. 1978. The identification of four new *meta*-depsides in the lichen *Ramalina asahinae. Aust. J. Chem.,* **31**: 2745–2749.

CHESTER, D.O. & ELIX, J.A. 1979. Three new aliphatic acids from lichens of genus *Parmelia* (subgenus *Xanthoparmelia*). *Aust. J. Chem.,* **32**: 2565–2569.

CULBERSON, C.F. 1972. Improved conditions and new data for the identification of lichen products by a standardized thin-layer chromatographic method. *J. Chromatogr.* **72**: 113–125.

CULBERSON, C.F. & JOHNSON, A. 1982. Substitution of methyl *tert*.-butyl ether for diethyl ether in the standardized thin-layer chromatographic method for lichen products. *J. Chromatogr.,* **238**: 483–487.

HALE, M.E. Jr. 1976. A monograph of the lichen genus *Pseudoparmelia* Lynge (Parmeliaceae). *Smithson. Contrib. Bot.,* **31**: 1–62.

KUROKAWA, S. 1985. Studies on Australian and Tasmanian species of *Parmelia* (2). *Bull. natn. Sci. Mus Tokyo,* Ser. B (Bot) **11**(3): 77–90.

KUROKAWA, S. & FILSON, R.B. 1975. New species of *Parmelia* from South Australia. *Bull. natn. Sci. Mus. Tokyo,* Ser. B (Bot.) **1**: 35–48 + 4 pl.

Figures 3 to 7.

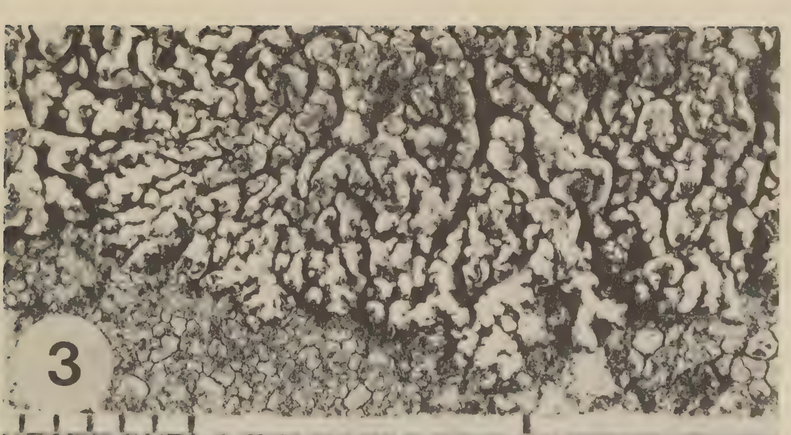
Fig. 3. *Parmelia fausta* Brusse, habit. *F. Brusse 4891*, holotype. Scale in mm and cm.

Fig. 4. *Parmelia insignis* Brusse, habit. *F. Brusse 4801*, holotype. Scale in mm and cm.

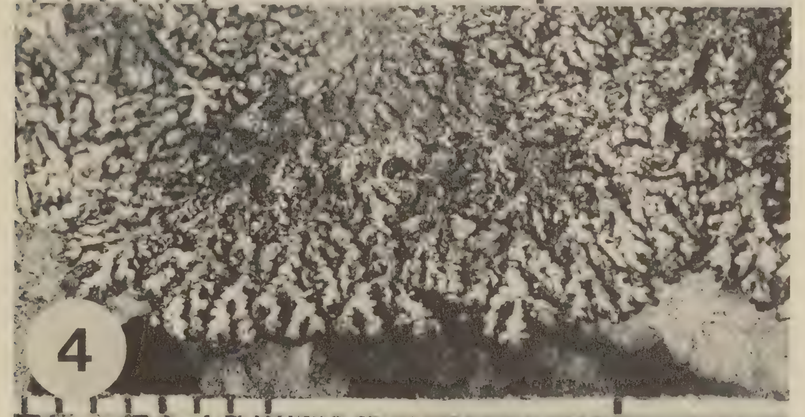
Fig. 5. *Parmelia inuncta* Brusse, habit. *F. Brusse 4810*, holotype. Scale in mm.

Fig. 6. *Parmelia eximia* Brusse, habit. *F. Brusse 4840*, holotype. Scale in mm and cm.

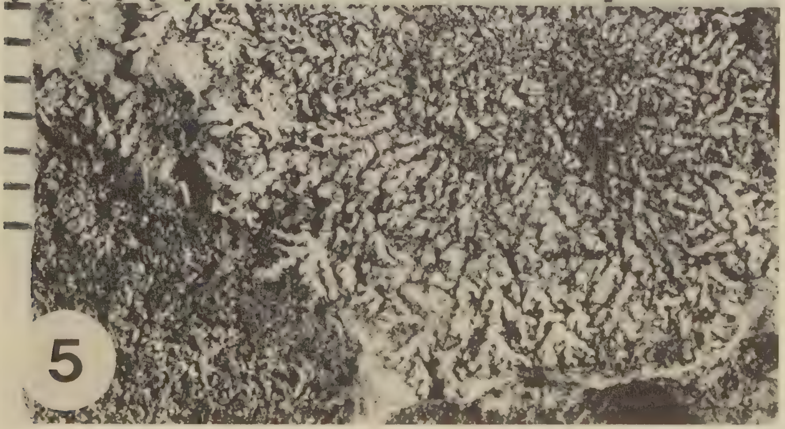
Fig. 7. *Parmelia pudens* Brusse, habit. *F. Brusse 4792*, holotype. The larger lobed lichen on the upper margin of this photograph is *Parmelia xanthomelaena* Müll. Arg.. Scale in mm and cm.



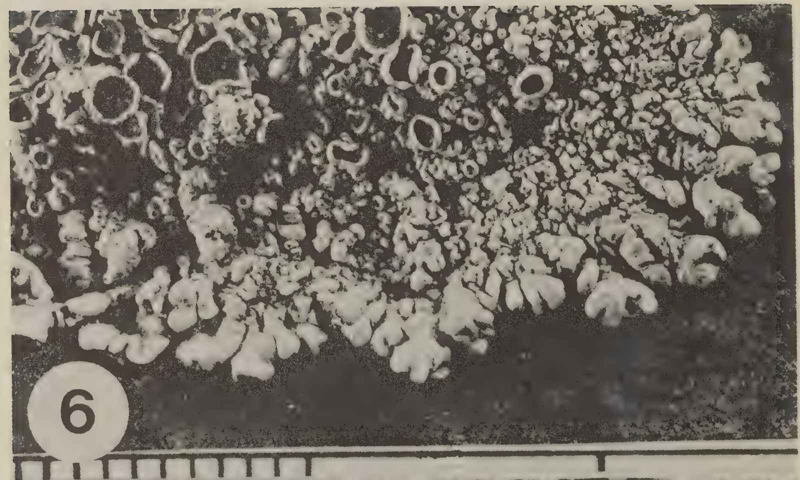
3



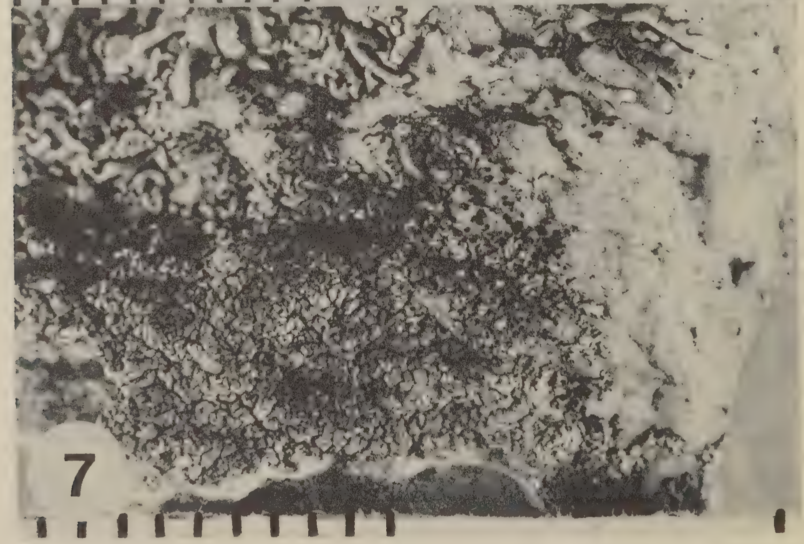
4



5



6



7

MYCOTAXON

Vol. XXVII, pp. 193-218 October-December 1986

HYPOGEOUS FUNGI FROM THE SOUTHEASTERN UNITED STATES I. THE GENUS *RHIZOPOGON* [1]

Steven L. Miller

Department of Forest Science, Oregon State University, Corvallis, Oregon 97331

SUMMARY

Eleven species of *Rhizopogon* from the southeastern United States are redescribed from fresh collections. New information on development and ectomycorrhizal host range are presented for *R. nigrescens*, *R. fuscorubens*, *R. succosus*, *R. fabri*, *R. rubescens*, *R. subaustralis*, *R. vulgaris*, *R. couchii*, *R. evadens* , *R. abietis*, and *R. truncatus*. *Rhizopogon atlanticus* is redescribed from dried material. Doubtful species for the southeastern United States are also discussed.

INTRODUCTION

Research on ectomycorrhizae in the southeastern United States has increased dramatically in the past decade. The need for taxonomic, systematic, and ecological knowledge of ectomycorrhizal fungi has also increased.

Species in the genus *Rhizopogon* are hypogeous members of the Hymenogastrales and are important ectomycorrhizal fungi in the southeastern United States. Zeller and Dodge (1918) first monographed *Rhizopogon* in North America, but no fresh collections were examined from the southeastern United States. In 1928 Coker and Couch included *Rhizopogon* in their study of eastern Gasteromycetes. Although accurate descriptions are provided, this work is no longer a modern treatment, and several important species are not included. Dr. Alexander Smith in Smith and Zeller (1966) produced the first modern account of the genus *Rhizopogon* and included the major taxa from the southeastern United States. Many of the collections, however, were described only from herbarium collections. Dr. Smith (Smith and Zeller 1966) admitted that the greatest disappointment in his investigation of *Rhizopogon* "was an inability to satisfactorily identify dried specimens in herbaria" without adequate notes, and he invited other investigators to apply his concepts to their respective floras.

This paper presents data on *Rhizopogon* from the southeastern United States. The ability to study fresh collections in all developmental stages provided me with insights not previously possible.

---

[1] Funded in part by the USDA Forest Service, Pacific Northwest Research Station, Corvallis, Oregon 97331 U.S.A.

METHODS AND MATERIALS

Methods of collection, terminology used, and classification were generally those of Smith (Smith and Zeller 1966). Colors are from the Methuen Handbook of Colour (Kornerup and Wanscher 1981) because of its accessibility. Herbarium names are abbreviated according to Lanjouw and Stafleu (1964). Portions of typical, freshly collected sporocarps were fixed overnight in 2% glutaraldehyde, dehydrated in ethanol and embedded in paraffin. After being sectioned, tissues were stained with safranin-fast green and permanently mounted. Fresh and dried specimens were examined with standard microchemical reagents, in addition to a saturated aqueous solution of Ruthenium red. Ruthenium red is a mucilage stain and readily differentiates brachybasidioles, thick-walled basidia, and certain spore walls. Ultrastructural investigations and ectomycorrhizal syntheses performed in conjunction with this study are being published separately.

Key to *Rhizopogon* species in the southeastern United States

1. Color of fresh, mature peridium dull or bright yellow, usually overall, but at least over a majority of the peridium..........2

1. Color of fresh, mature peridium various, but not distinctly dull or bright yellow overall at any point in development..........9

  2. Gleba streaked with light-colored veins of sterile tissue; gleba exuding a colorless or pink, viscous latex..........3

  2. Gleba homogenous in color or mottled with lighter or darker colors from insect damage or erratic maturation, but not streaked with veins of sterile tissue, and not exuding latex..........4

3. Fresh peridium light yellow to light orange with abundant, fine rhizomorphs loosely appressed over the entire surface; not bruising where handled; the gleba dark yellow brown at maturity, not translucent..........**3. *R. succosus***

3. Fresh peridium greyish yellow to dark greyish yellow, with abundant, fine innate rhizomorphs netting the surface; frequently flushing red where handled; the gleba brown and nearly translucent at maturity..........**4. *R. fabri***

  4. Spores mostly oblong to oblong-elliptical, thick-walled, with prominent sterigmal remains 1.5-2.0 µm long forming a wide "cupped," truncate base..........5

  4. Spores mostly subcylindric, subfusoid, ellipsoid or oblong, not noticeably thick-walled, without prominent sterigmal remains 1.5-2.0 µm long, and usually lacking a "cupped,"truncate base..........6

5. Fresh peridium vivid yellow, even when young; gleba dark yellowish brown at full development; spores measuring (5.5) 7.0-9.0 (11) x 3.0-5.0 µm..........**11. *R. truncatus***

5. Fresh peridium white when young, then dull yellow; gleba brownish orange at full development; spores measuring 7.5-9.0 x 3.0-4.0 µm..........**12. *R. atlanticus***

  6. Most spores measuring 10.5-13.0 x 3.5-5.0 µm..........**8. *R. abietis***

  6. Most spores measuring less than 10 um long and 2.5-4.0 µm wide, but some spores reaching 10.5-11.0 µm in length..........7

7. Rhizomorphs abundant near the base as a tangle of free-hanging, coarse, branching fibrils, and nearly absent above..........8

7. Rhizomorphs abundant or sparse overall, but not as a tangle of free-hanging fibrils near the base ....9. ***R. couchii***

    8. Spores mostly subcylindric to occasionally subfusoid, measuring 7.5-9.5 (10.5) x 2.5-3.0 µm; with a well-developed turf of inflated cells in the peridium...........7. ***R. vulgaris***

    8. Spores mostly subfusoid and angular, measuring 7.0-10.5 (11) x 3.0-4.0 µm; without a turf of inflated cells in the peridium ....6. ***R. subaustralis***

9. Rhizomorphs abundant to sparse, coarse or fine, conspicuous, turning dark brown or black with handling...10

9. Rhizomorphs abundant to sparse, but not turning black with handling.......................................11

    10. Fresh peridium tacky; white at full development, easily discoloring where handled to areas of yellow, pink and orange; rhizomorphs sparse, fine, innate appressed ....1. ***R. nigrescens***

    10. Fresh peridium dry; greyish orange, brownish orange, or reddish brown at full development, occasionally bruising red; rhizomorphs abundant, coarse, appressed above, a tangled network of loosely hanging fibers below................................2. ***R. fuscorubens***

11. Fresh mature peridium pale yellow, bruising red, in age mottled with large areas of brown or dark brown; spores measuring 7.0-10.5 x(2.5) 3.0-3.5 (4.5) µm.........................5. ***R. rubescens***

11. Fresh mature peridium white, yellowish brown to greyish orange, bruising instantly magenta; spores measuring (5.5) 6.0-8.0 x 2.5-3.0 (3.5) µm ....10. ***R. evadens*** var. ***evadens***

1. ***Rhizopogon nigrescens*** Coker and Couch, Gasteromycetes of Eastern United States and Canada, p. 30. 1928. Figures 1, 11.

ETYMOLOGY: Latin, nigrescens ("blackening"), referring to the distinctive peridium that is white at first, then mottled with a number of colors, and finally drying blackish or blackish brown.

BASIDIOCARPS: 1.5-4.5(6) cm diam, subglobose, turbinate, compressed or irregularly lobed. **PERIDIUM** surface in youth tacky, smooth, tomentose, soon becoming appressed felty, then unpolished above, easily cracked and wholly removed from young sporocarps; white when young, then mottled with pale yellow (4A-3), orange white (5A-2), or pinkish white (7A-2), remaining pale below and in depressions, becoming brownish orange (6C-5), greyish brown (6D-3) and finally dark brown (7F-6); bruising intense reddish brown (9D-5) in youth; in cross-section up to 0.5 mm thick, pale greyish red (9D-5). Rhizomorphs sparse, conspicuous at first, fine, innate-appressed above in scant reticulum, concolorous with the peridium but brown (6E-6) to dark brown (6F-6) where handled, inconspicuous as the peridium darkens. Dried peridium black or dark brown, rhizomorphs inconspicuous. **GLEBA**: Loculate, locules 1-3 per mm at full development, smaller when young, irregular in shape, cakelike in consistency in youth, becoming spongy-cartilaginous in age; white at first, then yellowish grey (3B-2), or greyish yellow (3B-3), bruising reddish brown (9D-5, 6) where cut in young specimens. Dried gleba greyish yellow (3B-3 to 4B-3). **ODOR** sweet, fragrant. **KOH** on peridial surface quickly brownish violet (11D-6) to greyish ruby (12D-6); negative to pinkish white on the gleba. **$FeSO_4$** on peridial surface slowly dark olive progressing to black; negative on the gleba.

SPORES: 6.0-9.0 x 2.0-3.0 (3.5) µm, oblong to subfusoid, basal scar present but not prominent; in KOH hyaline to pale yellowish singly, light olive brown in mass; in Melzer's reagent hyaline singly, light olive yellow in mass, mostly with 2-3 lipid droplets. **HYMENIAL ELEMENTS**: Basidia borne in a distinct hymenium, clavate, 15-35 x 5-8 µm, thin-walled and soon collapsing, mostly 4- and 6-spored, 8-spored common; brachybasidioles 10-30 x 6-12 µm, subglobose, clavate, or obovate, thin-walled in youth, thick-walled in age, not readily disarticulated in crush mounts. **GLEBA**: Trama of hyaline, cylindrical to swollen, loosely interwoven hyphae that are 2-6 (10) µm diam, highly refractive in KOH, thin-walled in youth, mucilaginous with age; oleiferous hyphae common in mediostratum, 5-15 µm diam, yellowish refractive in KOH and Melzer's reagent, cylindrical or irregularly swollen and contorted. Subhymenium cellular, 3-4 cells deep, cells 4-7 µm diam, hyaline, subglobose, elongated or cubical, mucilaginous with age. **PERIDIUM**: 370-550 µm thick; of tightly interwoven, cylindrical, rarely inflated, thin-walled hyphae, 3-10 µm diam, or compacted into hyphal strands, 10-30 µm diam, 8-15 cells thick, gelatinized in age; heavily encrusted amorphous pigment that is brownish orange in KOH and Melzer's reagent; oleiferous hyphae abundant, 5-15 µm diam, yellowish refractive in KOH and Melzer's reagent, cylindrical or irregularly swollen and contorted. Subcutis lacking. Clamp connections absent.

HABITAT AND SEASON: Common in the spring and fall from June through December, associated with 2- and 3-needle pines such as *Pinus virginiana*, and *P. taeda*. Hypogeous or erumpent.

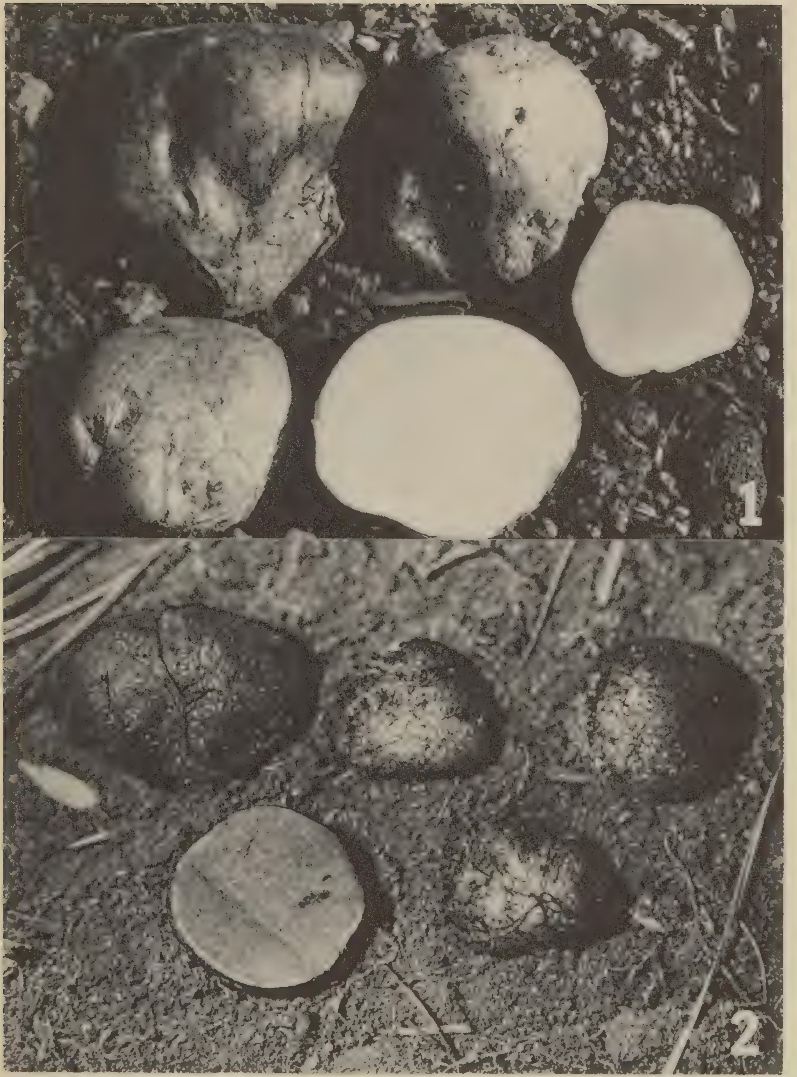
COLLECTIONS EXAMINED: LECTOTYPE: **North Carolina**: Bowlins Creek, Couch 7582 (NCU). **Florida**: Alachua Co., W. A. Murrill Autumn 1942, (TENN). **Maryland**: J. Trappe 5617, 5618 (OSC). **Mississippi**: Hancock Co., J. Trappe 4644 (OSC). **Virginia**: Montgomery Co., S. L. Miller 695 (OSC).

This species is perhaps the easiest species of *Rhizopogon* to identify in the southeastern United States. The small spores, multi-colored mottlings of the fresh peridium, and the uniform brownish black to black color of the dried peridium are unmistakable. The fact that the peridium of the younger sporocarps is readily separable from the gleba is a characteristic that should be compared with *R. couchii* and *R. evadens* also from the southeastern United States, and *R. separabilis* from the west coast of the United States.

2. *Rhizopogon fuscorubens* A.H. Smith, in Smith and Zeller, Mem. N.Y. Bot. Gard. 14:120-121, 1966. Figures 2, 12.

ETYMOLOGY: Latin, fuscorubens ("dark brown and reddening"), referring to the abundant dark brown rhizomorphs, and the reddish brown color often found in the peridium of older and dried basidiocarps.

BASIDIOCARPS: 1-5 cm diam, subglobose, ovate or turbinate. **PERIDIUM** surface dry, smooth, subtomentose in youth, felted below, unpolished above with age; white at first then pale yellow (4A-3), greyish orange (5B-4), brownish orange (5C-4, 5 to 6C-6), reddish brown (9C, D-5, 6) or brown (7E-4, 5 to 7F-4, 5) in age or where exposed; not bruising readily where injured; in cross-section 0.3-0.5 mm thick, yellowish white (3A-3) to reddish white (7A-2). Rhizomorphs abundant, circumscribing entire basidiocarp in a reticulate pattern, fine to large, mostly appressed, some free converging below into a tangled network of loosely hanging strands or single large rhizomorphic attachment; concolorous at first with fresh peridial surface and inconspicuous; readily staining brown (7F-4, 5), dark brown (7, 8F-8), or black in age or where handled, contrasting sharply with the lighter background peridial color. Dried peridium pale yellow (4A-2, 3) to light brown (7D-5, 6) with abundant brownish red (8C-5, 6), reddish brown (8D-5, 6), or black mottling; rhizomorphs visible but conspicuous only on young, pale peridium. **GLEBA**: Loculate, locules 3-4 per mm at full development; firm fleshy at first, then spongy-cartilaginous; white in youth, then dull yellow (3B-3, 4), greyish yellow (4C-4,5), finally light brown (5D-4,5) with age, often



Figs. 1-2. *Rhizopogon* spp. 1. *R. nigrescens* (SLM 695), x 4/5. 2. *R. fuscorubens* (SLM 804), x 1/2.

mottled with light zones caused by erratic maturation. Dried gleba yellowish white (4A-2) to greyish yellow (4B-4); hard but easy to section. **ODOR** absent to faintly metallic. **KOH** on peridial surface reddish brown (9F-7, 8); negative on the gleba. **$FeSO_4$** on peridial surface negative to slowly grey; negative on the gleba.

SPORES: (6) 7.0-9.5 x 2.5-3.0 µm, oblong to narrowly ellipsoid, basal scar present but not prominent; in KOH hyaline singly, pale greyish yellow in mass; in Melzer's reagent hyaline singly, bright orange yellow in mass, mostly with 1-3 false septa. **HYMENIAL ELEMENTS**: Basidia borne in a distinct hymenium, narrowly clavate, 15-20 x 5-8 µm, thin-walled and soon collapsing, mostly 8-spored; brachybasidioles 10-25 x 6-15 µm, subglobose, clavate or obovate, thin-walled in youth, moderately thick-walled to thick-walled, mucilaginous in age, not readily disarticulated in crush mounts. **GLEBA**: Trama of hyaline, cylindrical to slightly swollen, loosely interwoven hyphae that are 4-7 (10) µm diam, highly refractive in KOH, thin-walled in youth, thick-walled, mucilaginous with age; oleiferous hyphae present in mediostratum, 5-12 µm diam, hyaline refractive in KOH, yellowish refractive in Melzer's reagent; cylindrical or irregularly swollen and contorted. Subhymenium poorly developed, subcellular at base of some hymenial elements, 1-3 cells deep, cells 6-10 µm diam, hyaline, subglobose, cubical or elongated, branching, moderately thick-walled with age. **PERIDIUM**: 150-250 µm thick. Epicutis of tightly interwoven to appressed hyphae, 3-8 µm diam with hyaline thin to moderately thickened walls; rhizomorphs and hyphal strands abundant, 15-60 µm diam, 5-15 cells thick, tightly appressed or scattered throughout, hyphae subparallel in tangential-section, spherical in cross-section, resembling nests of sphaerocysts; gelatinized in age; heavily encrusted with dark brownish red amorphous pigment in KOH, pigment readily liquefying into large, compound reddish brown pigment globules in Melzer's reagent. Subcutis present at the interface between cuticle and mediostratum of tramal plates and comprising the outer portion of locules proximal to the cuticle, zone thin, cells mostly anticlinal, 10-15 x 5-8 µm diam, oblong to elongated or swollen, thin-walled, projecting into outermost locules; not encrusted. Clamp connections absent.

HABITAT AND SEASON: Found late in the fall from October to December associated with 2- and 3-needle pines such as *Pinus serotina* and *P. rigida*. Hypogeous or erumpent in forests, usually under a deep litter layer.

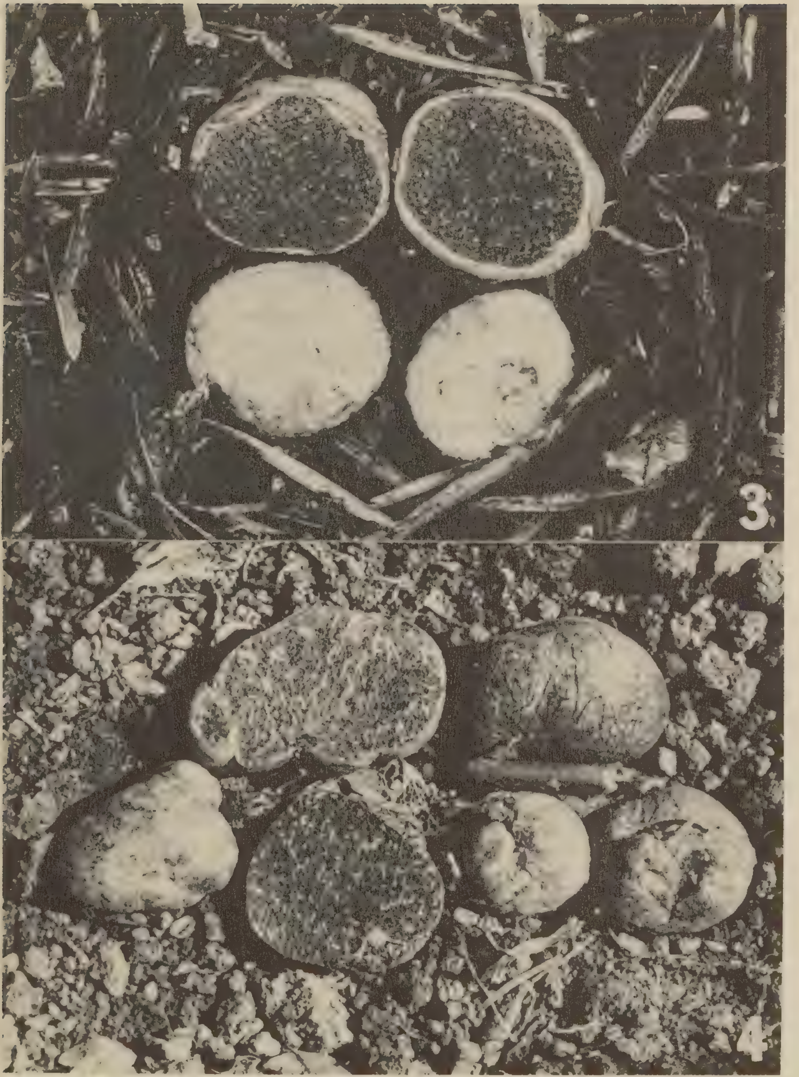
COLLECTIONS EXAMINED: HOLOTYPE: **Oregon**: Oswald 10-10-63 (MICH); Lane Co., J. Trappe 4751, 4836, 4837, (OSC). **Massachusetts**: Franklin Co., R. E. Halling 3556 (OSC). **Virginia**: Princess Anne Co., S. L. Miller 804 (OSC); M. A. Castellano 101 (OSC).

This species is easily recognized by its abundant, conspicuous dark brown to black rhizomorphs against a pale background peridium color, red to reddish brown peridium in older or slightly dried specimens and small spores. Dried specimens can look very similar to *R. nigrescens* but are generally pale to light yellow or entirely red mottled with black, rather than entirely black.

3. *Rhizopogon succosus* A. H. Smith, in Smith and Zeller, Mem. N.Y. Bot. Gard. 14:115-116, 1966. Figures 3, 13.

=*Rhizopogon lowii* A. H. Smith in Smith and Zeller, Mem. N.Y. Bot Gard. 14:55, 1966.
=*Rhizopogon superiorensis* A. H. Smith, Mich. Bot. 5: 20-21, 1966.

ETYMOLOGY: Latin, succosus ("succulent," "juicy"), referring to the colorless, viscous latex present in the gleba of mature sporocarps.



Figs. 3-4. *Rhizopogon* spp. 3. *R. succosus* (SLM 723), x 2. 4. *R. fabri* (SLM 691), x 2.

BASIDIOCARPS: 1-3 cm diam, mostly subglobose to ovoid or turbinate. **PERIDIUM** surface dry, smooth, subtomentose in youth, felted to appressed felty; pallid white to yellowish white (4A-2) or pale yellow (4A-3) in youth, then light yellow (4A-4) to light orange (5A-4) in age, mottled with brownish red (9C-6), reddish brown (9D-6) or brown (6E-6); not bruising where handled; in cross-section, 0.4-0.5 mm thick, pale yellow. Rhizomorphs abundant over entire surface, fine, loosely appressed above, free below forming a tangled network of loosely hanging fibrils, often with a single large rhizomorphic attachment; pale yellow (4A-3), light yellow (4A-4) or light orange (5A-4), darkening only slightly when handled. Dried peridium uniformly reddish brown (8E-7 to 9E-7). **GLEBA**: Loculate, locules 3-4 per mm, irregularly shaped; cakelike in consistency in youth, firm and rubbery in age; exuding a hyaline, viscous latex when cut; white when young, becoming olive (2E-4), then dark olive brown (4F-8), dark yellowish brown (5F-4, 5); groups of locules separated by pallid white veins. Dried gleba unchanged from fresh coloration; glassy hard. **ODOR** fruity at maturity. **KOH** on peridial surface dark brownish red; on the gleba olive green (1E-8). **$FeSO_4$** on peridial surface slowly dark olive brown (4E-5); negative on the gleba.

SPORES: 7.5-10.5 (13) x 3.0-4.0 µm, oblong, fusiform-elliptical, naviculate, reniform or irregularly bent, occasionally subangular or bilobed, smooth, basal scar prominent; in KOH, pale yellowish olive singly, light olivaceous in mass; in Melzer's reagent, pale yellowish singly, yellow brown in mass, mostly with one large lipid droplet. **HYMENIAL ELEMENTS**: Basidia borne in a hymenial layer or from various levels within the mediostratum, clavate to irregularly contorted and swollen, 16-25 x 5-7 µm, thick-walled at first, easily disarticulated in crush mounts, soon collapsing, 1- and 2-spored; brachybasidioles 15-30 x 6-9 (12) µm, clavate to obovate, thin-walled in youth, thick-walled, mucilaginous in age, easily disarticulated. **GLEBA**: Trama of hyaline, cylindrical to swollen and knobby, loosely interwoven hyphae that are 2-5 (8) µm diam, refractive in KOH and Melzer's reagent, thin-walled in youth, mucilaginous with age. Subhymenium absent. **PERIDIUM**: 230-370 µm thick; of tightly interwoven, cylindrical to inflated, thin- or thick-walled hyphae, 5-15 µm diam; large highly vesiculose cells common near the surface, 15-30 µm diam, subglobose to elongated, mostly thick-walled, commonly in small clusters, often tearing to form large air pockets; hyphal strands abundant, innate appressed or scattered throughout, (15) 20-30 µm diam, 4-7 cells thick, commonly with one to several large cells surrounded by smaller cells, hyphae subparallel in tangential section, spherical in cross-section, resembling nests of sphaerocysts. Subcutis not well differentiated, similar to cutis but usually lacking large, inflated cells. The entire cutis gelatinized in age, heavily encrusted with amorphous pigment masses that are magenta to reddish brown in KOH, and brownish orange in Melzer's reagent. Clamp connections absent.

HABITAT AND SEASON: Common in the fall from October to December, associated with *Pinus strobus*, *P. taeda*, and *P. banksiana*. Hypogeous under thick needle-litter layer.

COLLECTIONS EXAMINED: HOLOTYPE: **North Carolina**: Chapel Hill, Coker 9889 (NCU); 13626 as *R. lowii* (NCU); Uwharrie Nat. Forest, S. L. Miller 723 (OSC). **Michigan**: Luce Co., A. H. Smith 71953 as *R. superiorensis* (MICH). **Tennessee**: Blount Co., 9669 (TENN). **Virginia** Buckingham Co., S. L. Miller 700 (OSC); Montgomery Co., O. K. Miller 20343 (VPI). **Canada**: Ontario, Dunsmore township, C. Godbout 1004 (OSC). **Mexico**: Chiapas, Lagunas de Montebello Nat. Park, J. Trappe 3324 as *R. superiorensis* var. *Mexicana* (OSC); J. Trappe 3327, 3331 (OSC).

I have collected all developmental stages of this fungus and find that *R. succosus* , *R. superiorensis* and *R. lowii* are identical. *Rhizopogon lowii* corresponds to younger, less well-developed sporocarps, but the type of *R. succosus* is overmature and was probably quite gelatinous when first collected. Of the species synonymized here, *R. superiorensis* is the only one that Dr. Smith was able to collect fresh. The color change from yellow when fresh to brownish red as dried is remarkable for *Rhizopogon* and admittedly causes confusion in herbarium material. *Rhizopogon succosus* is an appropriate name because of the viscous latex and the flabby nature of the senescent gleba.

Two distinct sizes of spores can be found within basidiocarps of *R. succosus*. Collections from the southeastern United States, Michigan, and Quebec have a greater proportion of spores in the larger size and the material labeled *R. superiorensis* var. *mexicanus* Hosford & Trappe has a greater proportion of spores in the smaller size. In all other respects, the Mexican material agrees with the United States collections and therefore is recombined as *R. succosus* A. H. Smith var. *mexicanus* (Hosford & Trappe) S. L. Miller (basionym, *R. superiorensis* var. *mexicanus* Hosf. & Trappe, Bol. Soc. Mex. Mic. 14: 11. 1980).

The fresh peridium of *R. succosus* appears to be mottled with reddish colors but this is not a staining or bruising reaction. Coloration, in conjunction with the thick-walled mucilaginous brachybasidioles and glass-hard glebal consistency when dried, suggests a close affinity to *R. luteolus* and more proper placement in the Stirps Luteolus rather than the Stirps Rubescens of Smith's classification.

4. ***Rhizopogon fabri*** Trappe, Nova Hedwigia 51:307, 1975. Figures 4, 14.

=*Rhizopogon piceus* sensu Coker and Couch, Gasteromycetes of Eastern United States and Canada, p. 34, 1928, non Berkeley andCurtis, Amer. Acad. Arts Sci. Proc. 4: 129, 1860.

ETYMOLOGY: Latin, genitive of faber ("smith"), in honor of Prof. Alexander H. Smith.

BASIDIOCARPS: 1-2 cm diam, mostly subglobose, compressed or reniform, or occasionally one to several lobed. **PERIDIUM** surface dry, smooth, subtomentose in youth, becoming felted, unpolished in age; white to pallid white when young, then greyish yellow (4B-3), dark greyish yellow (4C-5), remaining white to greyish yellow below and between lobes, but mottled with brown (6E-7) above; young sporocarps when handled showing a pale red flush; in cross-section, 0.2-0.3 mm thick, dark greyish yellow (4C-5) or brown (6E-7). Rhizomorphs abundant, conspicuous in age, fine, innate fibrils netting the entire surface, 1-3 large, cylindrical rhizomorphs protruding from basal attachment; concolorous with the young peridium, then dark olive brown (5E-4) to (5F-8), strikingly darker than peridium. Dried peridium pastel yellow (3A-4) mottled with large areas of brownish black (7F-4) to black. **GLEBA**: Loculate, locules 3-4 per mm, filled with spores in age, tough, rubbery; exuding a scant, pinkish yellow, viscous latex when freshly cut; white at first, then olive (3D-4), finally at maturity brown (6E-6, 7), nearly translucent; delimited into small groups by whitish or pale yellow veins. Dried gleba brown (6E-6, 7) to light brown (7E-6, 7); glassy hard. **ODOR** sweet, fungal. **KOH** on peridial surface quickly reddish brown (9D-5, 6); negative on the gleba or merely darker. **$FeSO_4$** on peridial surface slowly darker olive than background color; negative on the gleba.

SPORES: 7.5-11.0 x 3.0-4.0 (4.5) µm, oblong, fusiform-elliptical, or irregularly subangular or bent, smooth, basal scar present but not prominent; in KOH, pale yellow singly, olive brown in mass; in Melzer's reagent, yellowish singly, golden yellow in mass, mostly with 2-3 lipid droplets; completely filling the chambers in age. **HYMENIAL ELEMENTS**: Basidia borne in hyphal stuffed chambers at first, then from various levels within an irregular hymenium, clavate to elongate-clavate, 15-40 x 5-7(9) µm, thick-walled at first, soon collapsing, mostly 8-spored, commonly 2-, 4-, and 6-spored; brachybasidioles 15-35 x 7-12 µm, clavate to obovate or subglobose, thin-walled in youth, thick-walled, mucilaginous in age, easily disarticulated in crush mounts. **GLEBA**: Trama of cylindrical to swollen hyphae that are 2-10 µm diam, refractive in

KOH and Melzer's reagent, tightly interwoven in the mediostratum, thick-walled, highly gelatinized near the glebal chambers; oleiferous hyphae common in the mediostratum, 2-5 µm diam, yellowish refractive in KOH and Melzer's reagent, contorted and irregularly swollen, branching. Subhymenium cellular, not well differentiated, 3-6 cells deep; cells 3-7 µm diam, hyaline or yellow refractive in KOH and Melzer's reagent, subglobose, to elongated or irregular, thick-walled, highly gelatinized with age. **PERIDIUM**: 90-130 µm thick; of loosely interwoven, cylindrical to inflated, thin- or thick-walled hyphae, 2-8 (10) µm diam near the surface, more tightly compact near the glebal chambers; large, vesiculose cells common near the surface, thin-walled, readily collapsing to form large air pockets; oleiferous hyphae common, 2-5 µm diam, yellowish refractive in KOH and Melzer's reagent, cylindrical to contorted and irregularly swollen, branching; hyphal strands common, innate-appressed, scattered throughout, 8-20 µm diam, 2-5 cells thick, generally composed of cells of various sizes, subparallel in tangential-section, spherical in cross section, resembling nests of sphaerocysts; entire cutis gelatinized in age; heavily encrusted with amorphous pigment masses that are reddish brown in KOH, yellowish brown in Melzer's reagent, and readily liquefying into small, yellowish pigment globules. Subcutis lacking. Clamp connections absent.

HABITAT AND SEASON: Not common, found from summer to late fall, but mostly November to January, associated with *Pinus rigida*, and *P. palustris*. Hypogeous under deep humus in moist, rich soil.

COLLECTIONS EXAMINED: HOLOTYPE: **North Carolina**: Chapel Hill, Coker 6069 (NCU); Scotland Co., J. Trappe 8688 (OSC). **Virginia**: Giles Co., S. L. Miller 519, 691 (OSC); T. M. Flynn 443 (VPI).

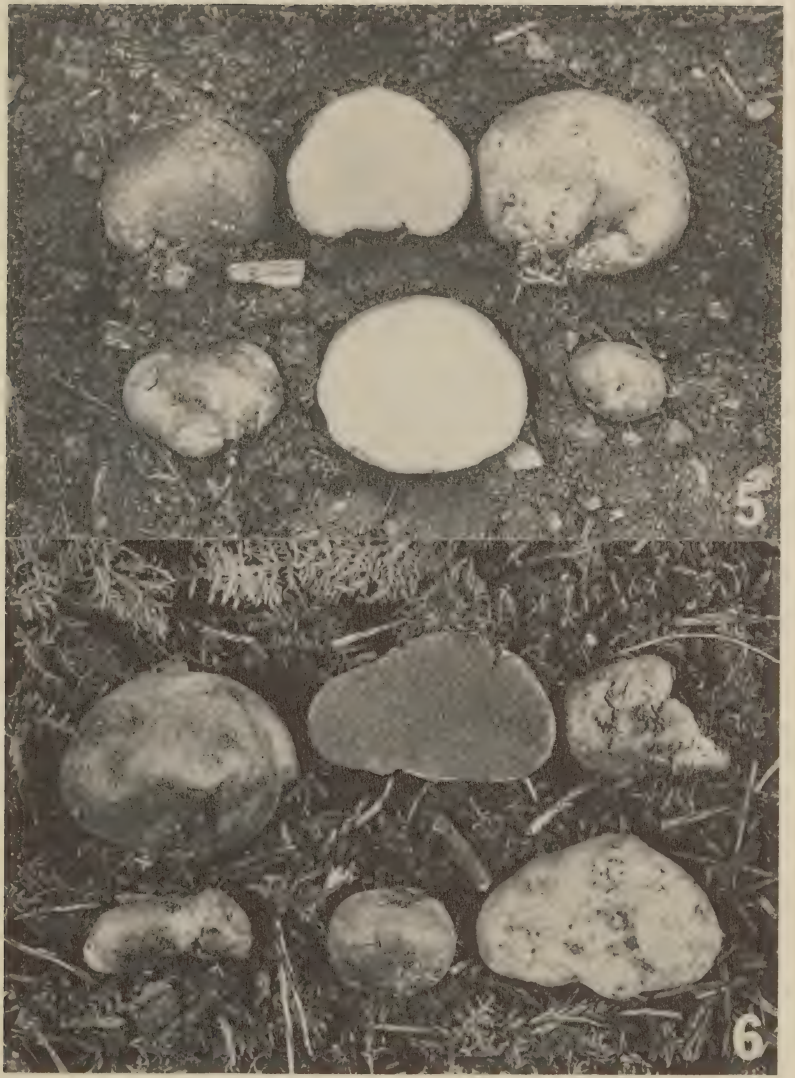
This is an unusual fungus. The nearly translucent gleba, viscous latex, and pallid white veins initially suggest placement in the genus *Alpova*. In addition, the young glebal chambers are completely filled with hyphae, at maturity the chambers are completely filled with spores, and the basidia in older sporocarps arise from various levels within an irregular hymenopodium. This fungus, however, has a definite layer of hymenial elements, primarily thick-walled, mucilaginous brachybasidioles, which preclude its placement in *Alpova* in the modern sense.

The ultrastructure and development of the locules and hymenium are being studied to determine the affinities of this fungus. The mucilaginous brachybasidioles and glass-hard consistency when dried are consistent with Smith's Stirps Luteolus in *Rhizopogon*. If this fungus were placed in *Alpova* it would likely be related to *A. klikae* in the subgenus *Antridium*.

5. ***Rhizopogon rubescens*** (Tul.) Tulasne, Giorn. Bot. Ital. 2:58, 1844.
Figures 5, 15.

ETYMOLOGY: Latin, rubescens ("reddening"), referring to the dull red bruising reaction of the fresh peridium.

BASIDIOCARPS: 1-3 cm diam, subglobose, ovoid, turbinate, or elongate flattened, furrowed to the base. **PERIDIUM** surface smooth, dry, cottony fibrillose in youth, then felted, finally appressed-felted below, areolate above; white when young, then yellowish white (3A-2) to pale yellow (3A-3, 4A-3), greyish yellow (4B-3) or pale orange (5A-3), in age mottled with brown (6E-7, 8) or dark brown (6F-7); young sporocarps bruising greyish red (10B-5) or brownish red (10D-7), older sporocarps bruising greyish red (9D-5, 6); in cross-section 0.5-1.0 mm thick; greyish red (9D-5). Rhizomorphs abundant in youth, prominent below and on the sides, innate-appressed, attached by 1-2 large, cylindrical or flattened rhizomorphs; white or pale yellow (4A-3); bruising greyish red (9D-5), then dark brown (6F-7). Dried peridium dark brown (6F-8 to 7F-8) or brownish black, with patches or streaks of yellow. **GLEBA**: Loculate,



Figs. 5-6. *Rhizopogon* spp. 5. *R. rubescens* (SLM 818), x 2/3. 6. *R. subaustralis* (SLM 726), x 1 1/4.

locules 1-3 per mm, irregularly shaped, empty at maturity; soft, cakelike at maturity, then tough, cartilaginous, in age gelatinous, flabby; white at first, then greyish yellow (4C-3, 4) to olive brown (4D-4), often mottled with lighter colors or maturing centrifugally with lighter colored tissue near the peridium. Dried gleba unchanged from fresh coloration; waxy, easy to section. **ODOR** slight, sweet-fungal in youth; in age strong, distinctly of road tar. **KOH** on peridial surface reddish brown (8E-7) or (9E-7), in time, dark brown; negative on the gleba. **$FeSO_4$** on peridial surface negative, or very slowly olive brown; negative on the gleba.

SPORES: 7.0-10.5 x (2.5) 3.0-3.5 (4.5) µm, subfusoid, ovate or broadly ellipsoid, basal scar distinct but not prominent, smooth or minutely punctate; in KOH, hyaline to yellowish singly and in mass; in Melzer's reagent, hyaline to yellowish singly and in mass, mostly with 2-3 lipid droplets. **HYMENIAL ELEMENTS**: Basidia borne in a distinct hymenium, clavate, 15-35 x 5-7 µm, thick-walled at first, soon collapsing, mostly 4-spored, 6- and 8-spored basidia also common; brachybasidioles 10-30 x 6-12 µm, subglobose, clavate, obovate or ellipsoid, thin-walled in youth, thick-walled, mucilaginous in age, easily disarticulated in crush mounts; basidia, brachybasidioles, and spores often encrusted or filled with amorphous pigment in locules near the peridium. **GLEBA**: Trama of hyaline, highly refractive, cylindrical to slightly swollen, loosely interwoven hyphae that are 2-8 (10) µm diam, thin-walled in youth, mucilaginous with age. Subhymenium cellular, 2-4 (5) cells deep, cells 5-8 µm diam, subglobose to elongated, hyaline, thick-walled with age. **PERIDIUM**: 240-450 µm thick. Epicutis of loosely interwoven, cylindrical to slightly inflated, thin or moderately thick-walled hyphae, 2-5(10) µm diam; hyphal strands frequent, innate-appressed or scattered throughout, 10-30 µm diam, 2-4 (8) cells thick, hyphae parallel in tangential-section, spherical in cross-section, resembling nests of sphaerocysts; gelatinized in age, heavily encrusted with amorphous intra- and intercellular pigment that is reddish brown to dark brown in KOH, rich reddish brown in Melzer's reagent, and readily liquefies into small or large pigment globules. Subcutis present at interface between cutis and mediostratum of tramal plates and comprises the outer portion of locules near the cutis, zone thin, cells anticlinal, 10-20 x 5-9 µm diam, oblong, oblong-elliptical or swollen, mostly thin-walled, projecting into outermost locules; often encrusted with reddish brown pigment. Clamp connections absent.

HABITAT AND SEASON: Common throughout the fall from October to December associated with 2- and 3-needle pines such as *Pinus virginiana* and *P. taeda*. Hypogeous, erumpent or fully exposed in soil in well-developed, forested areas.

COLLECTIONS EXAMINED: LECTOTYPE: **France**, La teste de Buch, Tulasne October 1843 (K). **Michigan**: Luce Co. A. H. Smith 58188 (MICH); A. H. Smith 66451 (MICH). **Tennessee**: Knox Co., 18122 (TENN); Cades Cove, 20236 (TENN). **Virginia**: Giles Co., S. L. Miller 580, 581, 584, 586, 600, 688, 689,690, 815, 818 (OSC); Patrick Co., S. L. Miller 710, 711 (OSC); Roanoke Co., S. L. Miller 579 (OSC). **Canada**: Quebec, St. Augustine, C. Godbout 104 (OSC); Baie St. Paul, J. Trappe 6364 (OSC).

Confusion surrounding this species will undoubtedly continue until good field notes are consistently taken on fresh specimens. Traditionally any *Rhizopogon* species in the southeastern United States with yellowish coloration and a reddish bruising reaction has been assigned to *R. rubescens*. This includes *R. subaustralis*, *R. vulgaris*, *R. abietis*., and to a lesser extent *R. couchii*. *Rhizopogon rubescens* in the sense taken here has only a pale yellow fresh peridium that is soon mottled with large patches of red or reddish brown, and becomes areolate in age. *Rhizopogon subaustralis*, *R. vulgaris*, *R. abietis*, and *R. couchii* have a pronounced, long-lived yellow stage, with less tendency to become areolate. In addition, the gleba of *R. rubescens* and *R. couchii* remain quite green (olive) when mature, rather than brown, as in *R. subaustralis*, *R. abietis*, and *R. vulgaris*.

Dried material of *R. rubescens* and *R. subaustralis* is difficult to distinguish without adequate notes because the spores of both species are similar. *Rhizopogon subaustralis* spores are generally more fusoid at the apex and are typically more angular than the mostly oblong or cylindrical spores of *R. rubescens* . The spores of *R. vulgaris* overlap in size with those of *R. rubescens* but are much narrower. *Rhizopogon couchii* spores are shorter than those of *R. rubescens*, and those of *R. abietis* are longer and wider.

6. ***Rhizopogon subaustralis*** A. H. Smith in Smith and Zeller, Mem. N.Y. Bot. Gard. 14:115-116, 1966. Figures 6, 16.

=*Rhizopogon brownii* A. H. Smith in Smith and Zeller, Mem. N.Y. Bot. Gard. 14:102-103, 1966.

ETYMOLOGY: Latin, subaustralis ("somewhat southern"), referring to the distribution limited to the southeastern United States and Mexico.

BASIDIOCARPS: 1-4 cm diam, subglobose, reniform, or elongate flattened, often irregularly lobed. **PERIDIUM** surface smooth, dry, cotton-fibrillose in youth, then felted below, unpolished above in age; white at first, then pale yellow (4A-2), greyish yellow (4B-4, 4C-3) to pale orange (5A-3), then brownish orange (5C-5-7), golden brown (5D-5-8), in age brown (7E-4), reddish brown (7E-8) or dark brown (8F-6) where handled; young sporocarps bruising reddish brown (9D-5, 6); in cross-section 0.5-0.7 mm thick; reddish brown (9D-5). Rhizomorphs not abundant, appressed below, absent or sparse above, usually attached by one large cylindrical strand; concolorous with peridium; bruising greyish red (9D-5). Dried peridium brownish orange (5C-4), mottled with large patches of dark brown (7F-6) to black; rhizomorphs inconspicuous. **GLEBA**: Loculate, locules 3-4 per mm, irregularly shaped, empty at maturity; cakelike in consistency when young, then rubbery, finally cartilaginous; white at first, then pale yellow (4A-2), and finally greyish yellow (4C-4) or yellowish brown (5E-5, 7). Dried gleba light brown (5D-4-6) oryellowish brown (5E-5-7). **ODOR** fungal fruity. **KOH** on young peridial surface pale (10A-3) to dull red (10B-4); negative on the gleba. **$FeSO_4$** on young peridial surface olive black, often rapidly spreading; negative on the gleba.

SPORES: 7.0-10.5 (11) x 3.0-4.0 µm, oblong to subfusoid, smooth, basal scar indistinct, in KOH, hyaline, pale olivaceous singly, in Melzer's reagent, pale yellow singly, yellow to olive yellow in mass, mostly with 2-3 lipid droplets. **HYMENIAL ELEMENTS**: Basidia borne in a distinct hymenium, clavate, 20-35 x 4-6 µm, thin-walled at first, soon collapsing, 4- and 6-spored; brachybasidioles 5-15 x 5-8 µm, globose, obovate or ellipsoid, thin-walled in youth, thick-walled, mucilaginous in age, easily disarticulated in crush mounts. **GLEBA**: Trama of hyaline, loosely interwoven hyphae that are 3-9 (12) µm diam, thin-walled in youth, mucilaginous with age; oleiferous hyphae common in the mediostratum and near the peridium, 5-20 µm diam, yellowish refractive in KOH and Melzer's reagent, cylindrical to convoluted, branched. Subhymenium cellular, 2-3(4) cells deep, cells 3-7 µm diam, hyaline, subglobose or elongated. **PERIDIUM**: 370-500 µm thick; of loosely interwoven, cylindrical to slightly inflated, thin- or moderately thick-walled hyphae, 2-5 µm diam; hyphal strands common, innate-appressed or scattered throughout, 3-10 (15) µm diam, 3-5 cells thick, subparallel in tangential-section, spherical in cross-section, resembling nests of sphaerocysts; oleiferous hyphae common, 3-20 µm diam, yellowish refractive in KOH and Melzer's reagent, cylindrical or contorted, branched; cutis gelatinized in age, heavily encrusted with amorphous pigment that is reddish brown in KOH, olive brown in Melzer's reagent, readily liquefying into small or large pigment globules. Subcutis lacking. Clamp connections absent.

HABITAT AND SEASON: Occurring spring and summer, very common in the fall from October to November associated with 2- and 3-needle pines such as *Pinus virginiana*, *P. rigida*, and *P. echinata*. Hypogeous, erumpent, or fully exposed, usually in early successional, poorly developed forests, on rocky slopes, or disturbed areas.

COLLECTIONS EXAMINED: HOLOTYPE: **North Carolina**: Chapel Hill, 7450 (NCU); Uwharrie Nat. Forest, S. L. Miller 724, 726 (OSC). **Maryland**: J. Trappe 5616 (OSC). **Louisiana**: Livingston Parish, S. M. Zeller 7203 as *R. brownii*. **Mississippi**: Harrison Co., J. Trappe 4642 (OSC). **Virginia**: Montgomery Co., S. L. Miller 717, 718, 719 (OSC).

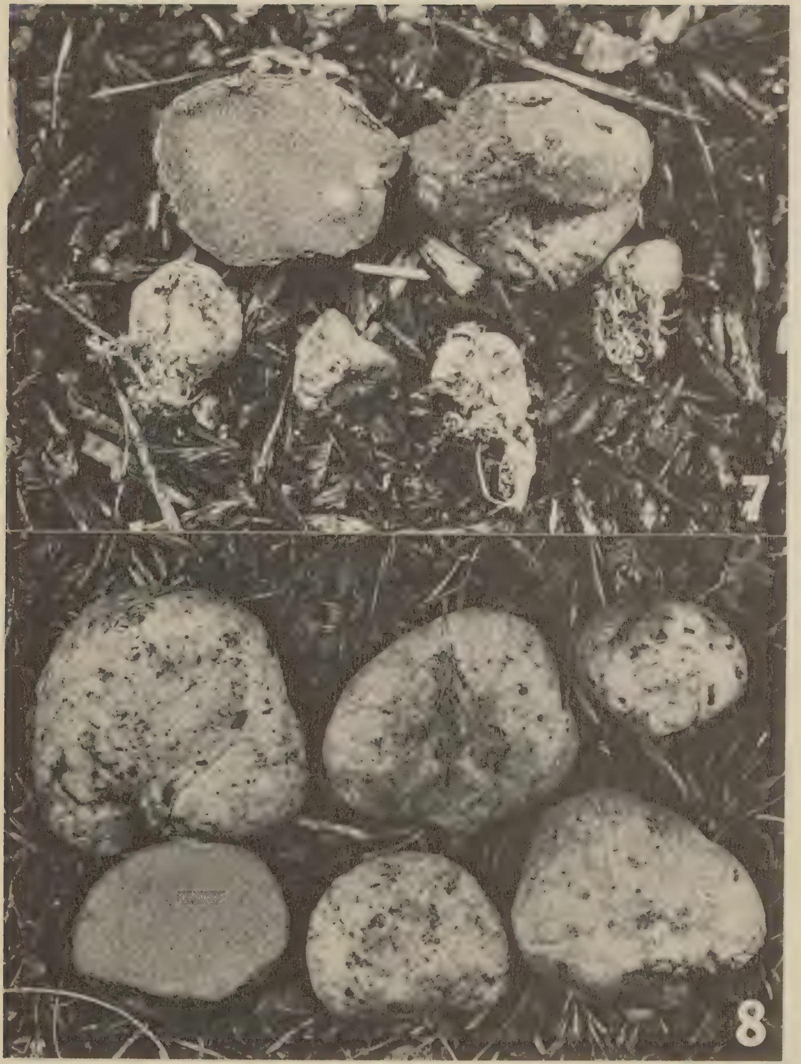
The importance of this species as an ectomycorrhizal fungus can only be assumed from the great abundance of its basidiocarps in the fall. *Rhizopogon subaustralis* differs from many species of *Rhizopogon*; it consistently occurs on disturbed or eroded banks and in early successional reforestation sites. *Rhizopogon subaustralis* would be a good candidate for inoculation onto nursery stock intended for less than optimal sites.

7. ***Rhizopogon vulgaris*** (Vitt.) M. Lange, Dansk Bot. Ark. Bd. 16, nr. 1, p. 56, 1956. Figures 7, 17.

ETYMOLOGY: Latin, vulgaris ("common," "ordinary"), referring to the fact that this fungus is widely distributed and commonly collected worldwide.

BASIDIOCARPS: 1-4 cm diam, subglobose, ellipsoid, flattened or irregularly lobed, frequently compound. **PERIDIUM** surface dry, smooth, cottony fibrillose in youth, then felted, shiny, metallic above in age after prolonged exposure; white when young and unexposed, then yellowish white (3,4A-2), pastel yellow (3A-4), finally greyish yellow (4C-5, 6) to olive brown (4D-5,6); white peridium bruising reddish white (9A-2), older or exposed peridium bruising brownish red (10D-6, 7) to violet brown (11E-5, 6); in cross-section 0.5-1.5 mm thick, thickest near the basal attachment, flushing dull red (10B-4). Rhizomorphs abundant near basal attachment, coarse, free hanging, profusely branched, rarely appressed over upper surface; white bruising reddish white (9A-2) when young, in age white to yellowish white (4A-2), often with no bruising reaction. Dried peridium greyish yellow (4B-3; 4C-4), often with patches of brighter yellow; rhizomorphs yellowish brown (5F-8), appressed, conspicuous near the base. **GLEBA**: Loculate, locules 4-5 per mm at full development; soft, cakelike at first, then tough, cartilaginous, in age gelatinous; white to yellowish white (2A-2) or pale yellow (2A-3) in youth, then olive yellow (3C-6), finally olive brown (4D, E-7) to yellowish brown (5E-4-8), often mottled light and dark because of erratic maturation; young specimens with pale gleba occasionally bruising pinkish white (7A-2). Dried gleba greyish yellow (4B-4) to yellowish brown (5E-8). **ODOR** similar to the commercial mushroom fresh, with age strongly of road tar. **KOH** on white peridium reddish white (9A-2), on yellow or olive areas brown (7E-7,8); negative on the gleba. **$FeSO_4$** on white peridium dull grey to blackish grey, negative on older peridium; negative on the gleba.

SPORES: 7.5-9.5 (10.5) x 2.5-3.0 µm, subcylindric, oblong to narrowly subfusoid, often curving slightly in profile, basal scar present but not prominent; in KOH, pale yellowish singly, dull yellowish grey in mass; in Melzer's reagent, pale yellow singly, dull olive yellow in mass, mostly with 2-3 lipid droplets. **HYMENIAL ELEMENTS**: Basidia borne in a distinct hymenium, subcylindric to narrowly clavate, 12-18 x 4-5 µm, thin-walled and soon collapsing, mostly 8-spored; brachybasidioles 10-20 x 6-10 µm, subglobose, clavate or obovate, thin-walled in youth, thick-walled, mucilaginous in age, not readily disarticulated in crush mounts. **GLEBA**: Trama of hyaline, cylindrical to slightly swollen hyphae that are 4-7 µm diam, highly refractive in KOH, thin-walled in youth, mucilaginous with age; oleiferous hyphae present in mediostratum, 6-12 µm diam, hyaline refractive to deep yellow in KOH and Melzer's



Figs. 7-8. *Rhizopogon* spp. 7. *R. vulgaris* (SLM 860), x 2/3. 8. *R. couchii* (SLM 716), x 4/5.

reagent, cylindrical or irregularly swollen and contorted. Subhymenium poorly developed, composed of hyaline, thin- or thick-walled, branching, cylindrical or cubical hyphae. **PERIDIUM**: 300-360 µm thick. Epicutis a turf of globose to ovoid, thin-walled, inflated cells. Subcutis a layer of appressed, interwoven, thin-walled cylindrical hyphae, 6-14 µm diam; oleiferous hyphae abundant, 8-20 µm diam, dark yellowish brown in KOH and Melzer's reagent, cylindrical or irregularly swollen and contorted, occasionally branching; slightly gelatinized in age, lightly encrusted with amorphous pigment that is orange brown to reddish brown in KOH, orange brown in Melzer's reagent, readily liquefying into large, compound orange brown pigment globules . Clamp connections absent.

HABITAT AND SEASON: Common in late summer to fall from July to December associated with a variety of conifers including *Pinus virginiana*, *P palustris*, and *P. elliotii* in the southeastern United States, and *P. ponderosa*, *P. contorta*, *P. monticola*, *Tsuga mertensiana*, and *Abies amabilis* in the western United States. Hypogeous to erumpent, usually in disturbed, harsh forest sites or eroded slopes.

COLLECTIONS EXAMINED: **Arkansas**: Montgomery Co., J. Trappe 6660, 6661 (OSC); Union Co., J. Trappe 7392, 7393 (OSC). **California**: Siskiyou Co., S. L. Miller 860 (OSC); J. Trappe 4020, 5639 (OSC). Florida: **Tallahassee**, 21068 (TENN). **Massachusetts**: Franklin Co., R. E. Halling 3555 (OSC). **Mississippi**: Picayune, W. Cibula 648, 650 (OSC). **Oregon**: Deschutes Co., J. Trappe 4503, 7666 (OSC); Union Co., J. Trappe 4757 (OSC). **Tennessee**: Knox Co., 6609 (TENN). **Virginia**: Montgomery Co., S. L. Miller 587 (OSC).

Rhizopogon vulgaris is similar to *R. subaustralis*, occurring primarily on disturbed, eroded, or less than optimal sites. Often even large basidiocarps when cut open will be immature, and mature basidiocarps are often connected via tangled rhizomorphs to dozens of small, white, flattened or irregularly shaped primordia.

As with *Rhizopogon succosus* and other species of *Rhizopogon*, the spores of *R. vulgaris* exhibit different spore-length ranges in different regions of North America and Europe. Svrcek (1958) describes several varieties of *R. vulgaris* to account for variation in spore length. *Rhizopogon vulgaris* var. *intermedius* Svrcek best fits the mean spore length of most of the material that I have examined from the southeastern United States. The type collection of *R. vulgaris* var. *intermedius* cited by Svrcek, however, is mentioned under *R. roseolus* var. *intermedius* in the front of the book, and validly described in Latin under *R. vulgaris* var. *intermedius* in the keys at the back of the book. I am not certain of Svrcek's intent, and because spore length in the southeastern United States material is highly variable and overlaps with several of the varieties described by him, I am not ascribing varietal status.

8. *Rhizopogon abietis* A. H. Smith, in Smith and Zeller, Mem. N.Y. Bot. Gard. 14:93-94, 1966. Figure 18.

ETYMOLOGY: Latin, abietis ("fir-associated"), referring to the collection of the type specimen of this species close to members of the conifer genus *Abies*.

BASIDIOCARPS: 1.5-4 cm diam, subglobose, ovoid or pyriform. **PERIDIUM** surface dry, to slightly tacky in aging sporocarps, smooth, cottony fibrillose in youth, then appressed felty; white when young or unexposed, pale yellow (4A-3) to light yellow (4A-4) or reddish yellow (4B-6) in age or where exposed; bruising pale red (9A-2) at first, bruised areas quickly turning brown (6E-8 to 7E-4) or reddish brown (8E-5-7); in cross-section 0.3-0.5 mm thick, bruising greyish red (7B-4). Rhizomorphs abundant below, appressed, converging into one or two coarse rhizomorphs at point of attachment, scattered to absent above; concolorous with peridium; readily bruising dull red (8B-3). Dried peridium light yellow (4A-4) to brown

(6E-6), often with patches of black. **GLEBA**: Loculate, locules 4-5 per mm at full development; cartilaginous even in youth, gelatinizing in age; white at first, then greyish yellow (4C-5), yellowish brown (5D-5 to 5F-4, 5, 6) in age. Dried gleba light brown (5C,D-5, 6) to brown (6E-5, 6); hard to bone hard but easy to section. **ODOR** faint, fungal-fruity when young, distinctly of road tar in age. **KOH** on peridial surface reddish brown (8E-7); negative on the gleba. **$FeSO_4$** on the peridium slowly greyish olive (4E-3); negative on the gleba.

SPORES: 10.5-13 (15.5) x 3.5-5.0 (5.5) µm, mostly subfusoid, ranging to ellipsoid or ovoid, often slightly curving in profile view, basal scar prominent, fine remnants of the sterigma projecting slightly beyond a truncate base; narrowly clavate spores, possibly conidia also present, 15-22 x 3-3.5 µm, truncate at base but mostly lacking sterigmal projections; in KOH, hyaline singly, pale olive grey in mass; in Melzer's reagent, pale yellow singly, greyish olive in mass, mostly with 2 lipid droplets. **HYMENIAL ELEMENTS**: Basidia borne in a distinct hymenium, 15-20 x 5-7 µm, mostly thin-walled and soon collapsing, but many with moderately thick walls supporting conidial spores, 2-, 4-, and 6-spored; brachybasidioles 8-20 x 6-10 µm, subglobose, clavate, or obovate, thin-walled in youth, thick-walled, mucilaginous in age, often with amorphous yellow refractive contents in KOH and Melzer's reagent, readily disarticulated in crush mounts. **GLEBA**: Trama of hyaline hyphae that are 4-7 µm diam, moderately refractive in KOH, cylindrical to swollen near septa, loosely interwoven, thin-walled in youth and in age, gelatinous; oleiferous hyphae abundant in mediostratum, 3-8 µm diam, hyaline refractive in KOH, yellowish refractive in Melzer's reagent, cylindrical or irregularly swollen and contorted, often branching. Subhymenium subcellular but poorly developed, composed of cubical or cylindrical and branching hyphae, thin-walled at first, thick-walled, mucilaginous in age. **PERIDIUM**: 220-260 µm thick; of hyaline, thin-walled, loosely interwoven, cylindrical hyphae, 4-10 µm diam, large inflated cells up to 15 µm diam common, with a turf of clavate terminal cells, 25-40 x 10-14 µm, cuticle not readily gelatinizing in age; interior portion lightly encrusted with yellow to orange yellow amorphous pigment in KOH and Melzer's reagent, turf cells free from encrusting material. Subcutis absent. Clamp connections absent.

HABITAT AND SEASON: Found in the fall from September to December. This species is associated with 2- and 3-needle pines such as *Pinus virginiana* and *P. taeda* in the southeastern United States, but is reported with *Tsuga*, *Abies* and *Picea* from the western states. Hypogeous under deep litter in well-developed forest cover.

COLLECTIONS EXAMINED: HOLOTYPE: **Idaho**: Valley Co., A. H. Smith 65348 (MICH). **California**: Siskiyou Co., J. Trappe 5374, 7603 (OSC). **Oregon**: Lane Co., J. Trappe 4654 (OSC); Marion Co., J. Trappe 876 (OSC). **Pennsylvania**: Clarion Co., J. Trappe 7717 (OSC). **Tennessee**: Knoxville, 19494 (TENN); Hardin Valley, 21614 (TENN). **Virginia**: Montgomery Co., S. L. Miller 589 (OSC).

Rhizopogon abietis is most similar to fresh collections of *R. vulgaris* in that both species are distinctly yellow, bruise red, and have a tangle of white rhizomorphs near the point of attachment. In *R. abietis* , however, the much longer, wider basidiospores, frequently with a knobby, crooked apex, are distinctive. The exceedingly long, thin spores found among the basidiospores are also distinctive and may be conidial in origin.

9. ***Rhizopogon couchii*** A. H. Smith, in Smith and Zeller, Mem. N.Y. Bot. Gard. 14:115-116, 1966. Figures 8, 19.

ETYMOLOGY: In honor of Dr. John N. Couch, who has collected hypogeous fungi in the southeastern United States for many years, and who refers to himself as William C. Coker's "truffle pig."

BASIDIOCARPS: 1-6 cm diam, subglobose, turbinate, angular, irregularly elongate and flattened, or lobed. **PERIDIUM** surface dry, smooth, subtomentose to felty in youth, then unpolished above, easily separable from gleba; white or yellowish white (4A-2) when young or covered with soil, then pale yellow (4A-3), light yellow (4A-4), or greyish yellow (4B-4, 5); in age or where handled, brownish orange (5C-4; 6C-3) or brown (6E-6), pale yellow (4A-3) below and in depressions; young sporocarps bruising reddish brown (9D-4), older sporocarps bruising light brown (7D-6), brown (7D-7) or reddish brown (8D-5); in cross-section 0.3-1.0 mm thick, reddish brown (9D-5). Rhizomorphs abundant, large, appressed below, fine, more reticulate above, fused to a single point of attachment; concolorous with peridium. Dried peridium brown (7E-7) or dark brown (7F-8); rhizomorphs inconspicuous. **GLEBA**: Loculate, locules 4-5 per mm in youth, in age larger, 2-3 per mm, irregularly shaped, empty at maturity; cakelike in consistency when young, then firm, moist, finally dry, cartilaginous; white at first, then dull yellow (3B-3), greyish yellow (3B-5 to 3C-3), finally olive brown (4D-5), maturing centrifugally; often bruising pale red (9A-3) to greyish red (9C-5) where exposed. **ODOR** fruity. **KOH** on peridial surface deep red to reddish brown; on gleba greyish red (8B-4, 5). **$FeSO_4$** on peridial surface slowly yellowish brown (5E-5-7 to 5F-5-7) or olive black; negative on the gleba.

SPORES: 5.5-8.5 x 2.0-3.0 µm, oblong to oblong-elliptical, smooth, basal scar indistinct; in KOH, hyaline singly, yellowish to olivaceous in mass; in Melzer's reagent, yellowish singly, olive yellow in mass, mostly with 2 lipid droplets. **HYMENIAL ELEMENTS**: Basidia borne in a well-developed hymenial layer, mostly clavate, 10-30 x 4-7 µm, thin-walled at first, soon collapsing, 4-, 6- or mostly 8-spored; brachybasidioles 6-10 x 5-6 µm, subglobose to obovate, hyaline, thin-walled in youth, thick-walled in age, gelatinized and pigment-filled or encrusted in age in locules proximal to the peridium. **GLEBA**: Trama of hyaline, cylindrical to inflated hyphae that are 2-5 µm diam, subparallel to interwoven, or pseudoparenchymatic adjacent to the chambers, thin-walled in youth, mucilaginous in age. Subhymenium cellular, 2-3 (4) cells deep, cells 4-10 µm diam, pale orange or yellow orange in KOH, yellowish in Melzer's reagent, globose, subglobose, or elongate. **PERIDIUM** 280-300 µm thick; of tightly interwoven, cylindrical or slightly inflated, thin-walled hyphae, 4-10 (15) µm diam; enlarged cells scattered near glebal chambers; hyphal strands present, innate-appressed or submerged, 20-40 µm diam, 3-10 cells thick, parallel in tangential-section, spherical in cross-section, resembling nests or sphaerocysts; gelatinized in age, heavily encrusted with amorphous pigment that is yellow to yellow brown in KOH, intense yellow to yellow brown in Melzer's reagent, intra- and intercellular near the surface, intercellular only near the locules. Subcutis lacking. Clamp connections absent.

HABITAT AND SEASON: Common late in the fall from October to December associated with 2- and 3-needle pines such as *Pinus virginiana*, *P. taeda*, and *P. resinosa*. Hypogeous or erumpent in forests, usually under a deep litter layer.

COLLECTIONS EXAMINED: HOLOTYPE: **North Carolina**: Chapel Hill, 6003 (NCU). **Florida**: Tallahassee, 20273 (TENN). **Tennessee**: Cades Cove, 4860 (TENN). **Virginia**: Montgomery Co., S. L. Miller 715, 716 (OSC). **West Virginia**: Pocahontas Co., S. L. Miller 504, 554 (OSC); O. K. Miller 19566 (VPI).

Rhizopogon couchii varies considerably in color. I have seen large, fully mature basidiocarps that are white, yellow, or brown, depending on the depth at which the sporocarps were found. The more exposed the peridium is, the darker the color. The abundant appressed rhizomorphs and yellowish color somewhere on the fresh peridium are enough to distinguish this species, however. The red bruising of the gleba is best demonstrated in fresh, moist, undamaged sporocarps.

Rhizopogon couchii, *R. vulgaris*, and *R. evadens* are similar when dried and are best identified when fresh. *Rhizopogon. couchii* has abundant rhizomorphs overall, but not white, loosely hanging rhizomorphs as in *R. vulgaris*. *Rhizopogon evadens* has only sparse rhizomorphs, is typically white, pale yellow to greyish orange and has a silky, greyish red flush overall. *Rhizopogon vulgaris* has a turf of inflated, ovoid hyphal end-cells in the peridium.

Rhizopogon smithii Hosford from coastal regions of the Pacific northwest shows similar color variation, rhizomorphic pattern, and red bruising of the gleba as in *R. couchii*. In addition, the spores of *R. smithii* are the same size as those of *R. couchii*. Further examination of these two species may warrant synonymy.

10. ***Rhizopogon evadens*** A. H. Smith var. ***evadens*** in Smith and Zeller, Mem. N.Y. Bot. Gard. 14:151-152, 1966. Figures 9, 20.

ETYMOLOGY: Latin, evadens ("escaping," "going out"), possibly because basidiocarps of this fungus are frequently erumpent.

BASIDIOCARPS: 1-5 cm diam, subglobose to elongate flattened, frequently irregularly lobed and folded. **PERIDIUM** surface dry, smooth, subtomentose at first, then appressed felty, often scurfy, in age silky; easily separable from gleba; white to yellowish white (4A-2) when young or unexposed, often pale yellow (4A-3) to yellowish brown (5D-5, 6) in patches, finally greyish orange (5B-3, 4 to 6B-3, 4); white peridium bruising greyish Magenta (13C, D-5, 6), older or exposed peridium discoloring to greyish red (7B-3, 4) or reddish brown (8 9D-5) where handled; in cross-section 0.5 to 1.0 mm thick, thickest near the base, white, flushing immediately greyish red (9C-4, 5). Rhizomorphs abundant, appressed, coalescing into a single large rhizomorphic attachment below, tapering to fine, scant fibrils above; concolorous with peridium at first, then brown (7E-5, 6) where handled. Dried peridium pale orange (5A-3) to light orange (5A-4) below and in depressions, brown (6E-4, 5 or 7E-5, 6) to dark brown (6F-4, 5) elsewhere; rhizomorphs dark brown (6F-4) and inconspicuous. **GLEBA**: Loculate, locules 4-5 per mm when young, up to 2-3 per mm at full development; soft, cakelike young, then tough, cartilaginous in age; white in youth, then greyish yellow (2C-3; 3B-5 to 3C-4), maturing centripetally with pale coloration proximal to the peridium; young or mature gleba often bruising pale red (9A-3) to dull red (9C-4). Dried gleba pale yellow (4A-3) to light yellow (4A-4), hard but easy to section. **ODOR** not distinctive to acidic disagreeable in age. **KOH** on peridium reddish brown (9D-6, 7); on young gleba often pinkish white (9A-2). **$FeSO_4$** on peridium slowly olive; negative on the gleba.

SPORES: (5.5) 6.0-8.0 x 2.5-3.0 (3.5) µm, narrowly oblong to ovoid, frequently curved in profile, basal scar present but not prominent; in KOH, hyaline to pale yellow singly, pale yellowish grey in mass; in Melzer's reagent, pale yellow singly, olive yellow in mass, mostly with 2-3 lipid droplets. **HYMENIAL ELEMENTS**: Basidia borne in a distinct hymenium, 15-25 x 5-6 µm, thin-walled and soon collapsing, narrowly clavate, 4-, 6-, or 8-spored; brachybasidioles 8-25 x 6-15 µm, subglobose, clavate or obovate, thin-walled to moderately thick-walled in youth, thick-walled, mucilaginous in age, readily disarticulated in crush mounts. **GLEBA**: Trama of hyaline, cylindrical to slightly swollen, loosely interwoven hyphae that are 3-8 µm diam, refractive in KOH, thin-walled in youth, highly gelatinous in age; oleiferous hyphae common in mediostratum, 4-13 µm diam, hyaline refractive in KOH, yellow refractive in Melzer's reagent, cylindrical or irregularly swollen and contorted, branching. Subhymenium poorly developed, composed of hyaline, thin-walled, cubical, elongated or branching cylindrical hyphae. **PERIDIUM**: 200-320 µm thick; epicutis of thin-walled, tightly appressed, parallel, gelatinous hyphae, 3-5 µm diam, heavily encrusted with dull yellow to orange yellow amorphous pigment in KOH, bright yellow orange in Melzer's reagent. Subcutis present but not well differentiated from epicutis, of thin-walled, cylindrical, non-gelatinous hyphae, 5-25 µm diam, with abundant hyphal strands appearing in cross-section as nests of sphaerocysts; oleiferous hyphae abundant, 5-12 µm diam, hyaline refractive in KOH, yellow refractive in Melzer's reagent, cylindrical or irregularly swollen and contorted, branching, lightly encrusted with dull yellow pigment or free from encrusting material. Clamp connections absent.

HABITAT AND SEASON: Found in the spring, summer and fall, but mostly from October to December. This species is associated with 2- and 3-needle pines such as *Pinus virginiana*, *P. taeda*, *P. palustris*, and *P. elliotii* in the southeastern United States, and *P. ponderosa*, *P. contorta*, *P. lambertiana*, and *Pseudotsuga menziesii* in the west.

COLLECTIONS EXAMINED: HOLOTYPE: **Idaho**: Custer Co., A. H. Smith 65484 (MICH). **Colorado**: Boulder Co., J. Trappe 5700, 8055 (OSC). **Mississippi**: Pearl River Co., W. Cibula 648, 649, 650, 656, 666, 669 (OSC); Santa Rosa, W. Cibula 670 (OSC); Saucier, W. Cibula 677 (OSC). **North Carolina**: Uwharrie Nat. Forest, S. L. Miller 725 (OSC). **Ohio**: Hocking Co., W. B. Cooke 41669 (OSC). **Oregon**: Deschutes Co., J. Trappe 8185 (OSC); Douglas Co., J. Trappe 343 (OSC); Jackson Co., J. Trappe 6285 (OSC); Josephine Co., J. Trappe 7040, 7429 (OSC). **Tennessee**: Cades Cove, 18150 (TENN). **Virginia**: Montgomery Co., S. L. Miller 705 (OSC).

Rhizopogon evadens is most often confused with *R. couchii* or *R. vulgaris* because of the small spores. *Rhizopogon evadens* , however, lacks the distinctly yellow peridium characteristic of the other two species in the field and typically will bruise much faster and turns more Magenta when young and fresh.

11. *Rhizopogon truncatus* Linder, Rhodora 26:196-197, 1924.

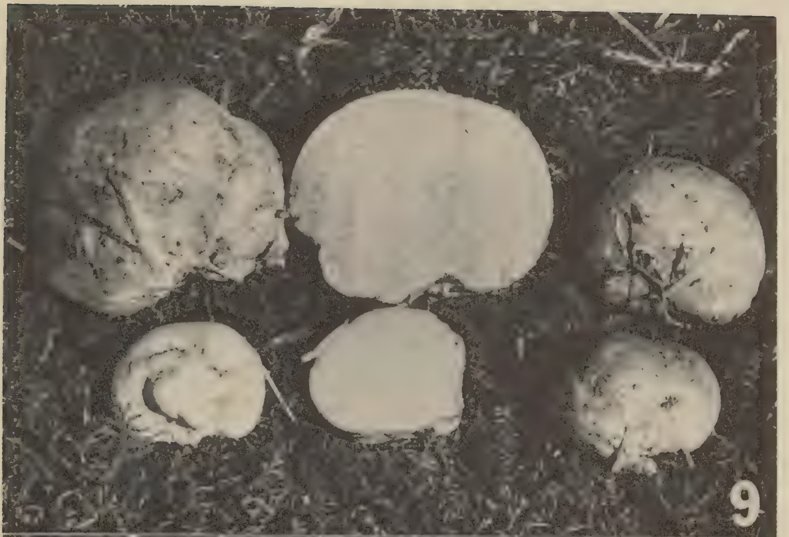
Figures 10, 21.

=*Rhizopogon cokeri* A. H. Smith in Smith and Zeller, Mem. N.Y. Bot Gard. 14:58-59, 1966.

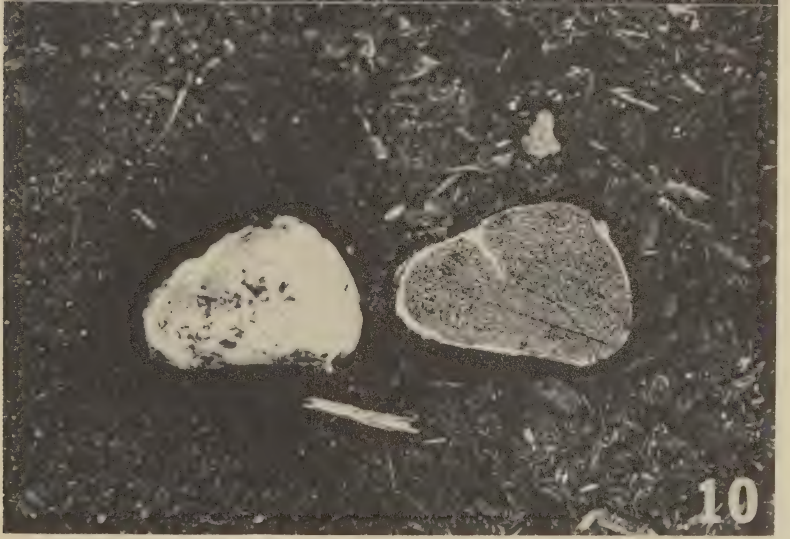
ETYMOLOGY: Latin, truncatus ("cut off"), referring to the truncate, prominent basal scar on the spores.

BASIDIOCARPS: 0.5-3 cm diam, globose, subglobose, or ovoid. **PERIDIUM** surface dry, granulose to pulverulent, unpolished where handled; yellow (3A-6) to vivid yellow (3A-8) even in youth, greyish yellow (2B-7 to 3B-7) or olive yellow (3C-7) where handled; not bruising; in cross-section 0.3-0.5 mm thick, yellow (3A-6). Rhizomorphs sparse, inconspicuous, fine, reticulating above, 1-3 large strands appressed below, concolorous with peridial surface. Dried peridium yellow (3A-6,7), often mottled with olive yellow (3C-7) or deep orange (6A-8). **GLEBA**: Loculate; locules small, 4-6 per mm, irregularly shaped, empty at maturity; soft, cakelike in consistency when young, firm in age; yellowish white (4A-2) to pale yellow (4A-3) at first, then greyish yellow (4B-4), dark olive brown (4F-8) or yellowish brown (5E-8), finally dark yellowish brown (6F-8). Dried gleba unchanged in color; easy to section. **ODOR** slightly oily or not distinctive. **KOH** negative on the peridial and glebal surface. **$FeSO_4$** negative on peridial and glebal surface.

SPORES: (5.5) 7.0-9.0 (11) x 3.0-5.0 µm, oblong, oblong-elliptical, cylindrical, or ellipsoid, frequently irregularly allantoid, reniform, subangular or bilobed, smooth truncate, the basal scar and sterigmal remains prominent, walls thickened at maturity; in KOH, hyaline to pale yellow singly, yellowish brown in mass; in Melzer's reagent, immature spores hyaline to strongly dextrinoid singly and in mass, mature spores pale yellowish brown to slightly dextrinoid in mass; mostly with 1-2 lipid droplets. **HYMENIAL ELEMENTS**: Basidia borne in hymenial layer, clavate, 11-14 x 4.5-5.5 µm, hyaline, thick-walled at first, then autolyzing, 6- or 8-spored; brachybasidioles subglobose to obovate, 7-10 x 6-8 µm, thick-walled, gelatinizing at maturity. **GLEBA**: Trama of hyaline, cylindrical to swollen hyphae that are 2-5 µm



9



10

Figs. 9-10. *Rhizopogon* spp. 9. *R. evadens* var. *evadens* (SLM 705), x 4/5. 10. *R. truncatus* (Dan Luoma 638), x 1 1/4.

diam, thin-walled in youth, mucilaginous, refractive in age, subparallel in the mediostratum, interwoven and gelatinized adjacent to the hymenium; scattered oleiferous hyphae present in the mediostratum, 5-10 (15) µm diam, refractive or yellowish refractive in KOH and Melzer's reagent. **PERIDIUM** 100-220 µm thick; of uniformly cylindrical to occasionally swollen , branching, anastomosing, thin-walled hyphae, 4-7 µm diam; end cells 3-40 x 4-6 µm diam, blunted or rounded at the tip, protruding or intertwined; in KOH, pale yellow, the pigment diffusing into the fluid; bright yellow in Melzer's reagent, the pigment lightly encrusting the hyphae, not diffusing into the fluid. Subcutis lacking. Clamp connections absent; short, stubby branches resembling false-clamps common.

HABITAT AND SEASON: Fairly common throughout the summer from July to November and occasionally in the spring. In the southeastern United States, this species is most commonly reported from forests containing *Tsuga canadensis*, but it also occurs with *Pinus resinosa*. On the west coast it is associated with *Tsuga mertensiana*, *Pseudotsuga menziesii*, and *Abies* spp. Hypogeous or imbedded in well-rotted conifer logs, or woody debris.

COLLECTIONS EXAMINED: HOLOTYPE: **New Hampshire**: D. H. Linder July 1922 (FH). **California**: Del Norte Co., J. Trappe 3000 (OSC); Siskiyou Co., J. Trappe 4588 (OSC). **North Carolina**: Highlands, Coker 10511, as *R. cokeri* (NCU); Blount Co., V. Cotter 745 (VPI). **Oregon**: Douglas Co., J. Trappe 350, 5945 (OSC); Jackson Co., J. Trappe 2893, 4694 (OSC); Josephine Co., J. Trappe 7051(OSC); Klamath Co., J. Trappe 5264 (OSC); Lane Co., J. Trappe 2183, 4652, 5933 (OSC). **Canada**: Nova Scotia, K. A. Harrison 7670 (MICH).

Rhizopogon truncatus is interesting and unusual for several reasons. Unlike most *Rhizopogon* species the pigment in the peridium is bright yellow, pulverulent and dissolves readily in ETOH, KOH, and only slightly less readily in water. The spores are hyaline to pale yellow when young, then strongly dextrinoid, and finally pale yellow brown to only slightly dextrinoid when older. The gleba reaches full development slowly and in most collections the color is pale yellow. At full development, however, the gleba is dark yellowish brown.

The type of *R. truncatus* was collected by Linder (1924) from the top of a stump among hemlock trees in a birch-hemlock woods, where it had presumably been left by a small mammal. The length of time it had been there is unknown.

Unpublished data from the author shows that *R. truncatus* spores have 4-6 wall layers, several of which develop after the spore is released from the basidium. The spores of Linder's original material are mostly collapsed and hyaline to pale yellow, as if they are young. The types of *R. truncatus* and *R. cokeri* differ only developmentally, and neither are fully mature. The type collection of *R. truncatus* is the younger of the two and perhaps weather-worn from its exposure on the stump. The difference in coloration between the two dried collections is conceivably caused by rainfall washing a portion of the bright yellow pigment from Linder's collection.

12. *Rhizopogon atlanticus* Coker and Dodge in Coker and Couch, Gasteromycetes of Eastern United States and Canada, p. 35, 1928. Figure 22.

ETYMOLOGY: Latin, atlanticus ("near the Atlantic") referring to the distribution limited to the southeastern United States bordering the Atlantic Ocean.

BASIDIOCARPS: 1-4 cm diam, subglobose, elongate, or ovoid. Peridium surface white when young, dull yellow with age; not bruising where handled. Rhizomorphs present but not abundant, large, innate-appressed, a single strand at point of attachment. Dried peridium brownish orange (5C-4-6) to light brown (6D-4, 5), mottled with dark brown (6F-8); rhizomorphs darker than peridium, but not conspicuous. **GLEBA**: Loculate, locules as dried small, 5-8 per mm, only partially filled at maturity; white when young, then buffy. Dried gleba brownish orange (5C-4-6) **ODOR** fragrant in older sporocarps. **KOH** on dried peridial surface quickly dark brown; merely darker on the gleba. **$FeSO_4$** on dried peridial surface negative; merely darker on the gleba.

SPORES: 7.5-9.0 x 3.0-4.0 µm, oblong to short cylindrical, often irregularly bent, truncate, basal scar and sterigmal remains prominent, walls thickened at maturity, smooth, in KOH, pale yellowish brown singly and in mass; pale yellow in Melzer's reagent, golden yellow in mass, mostly with 2 lipid droplets per spore. **HYMENIAL ELEMENTS**: Basidia borne in hymenial layer, clavate, 10-20 x 5.5-8 µm, collapsed as dried, mostly 4- or 8-spored; brachybasidioles 20-30 x 10-15 µm, thin-walled in youth, thick-walled, mucilaginous in age, not easily disarticulated in crush mounts, heavily gelatinized. **GLEBA**: Trama of hyaline, cylindrical, hyphae that are 3-5 µm diam, loosely interwoven near the hymenium, subparallel in the mediostratum, mucilaginous with age, highly refractive in KOH. Subhymenium cellular, not well defined, 1-2 cells deep, cells 5-10 µm diam, globose to subglobose, hyaline, thick-walled with age. **PERIDIUM**: 300-450 µm; of loosely interwoven, cylindrical but knobby, swollen, highly branched, moderately thick-walled hyphae, 3-5 µm diam; hyphal strands common, scattered throughout, 10-25 µm diam, 3-8 cells thick, twisted into small knots of hyphae; oleiferous hyphae common, scattered throughout, 3-5 µm diam, yellowish refractive in KOH and Melzer's reagent, cylindrical, knobby or contorted and irregularly swollen; in KOH, pale yellow, the pigment diffusing into the fluid; encrusted with yellowish refractive pigment masses in Melzer's reagent. Subcutis thin or absent, composed of highly gelatinous or oleiferous hyphae. Clamp connections absent.

HABITAT AND SEASON: Hypogeous just below the surface of the humus in low damp pine woods. December.

COLLECTIONS EXAMINED: HOLOTYPE: **South Carolina**, Hartsville, Coker 5999 (NCU).

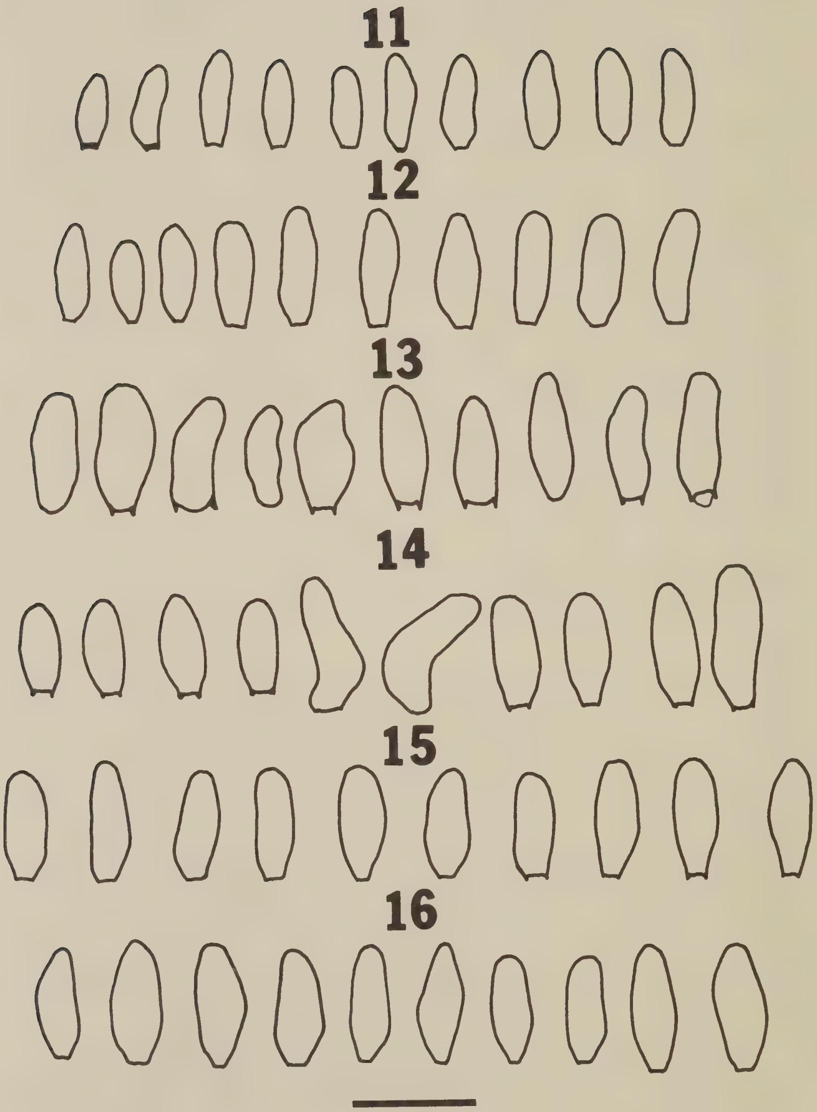
I have not collected this fungus fresh. The spores resemble *R. truncatus* in shape and overall morphology but are narrower and not dextrinoid at any point in development. The length of the sterigmal remains on the spores is also consistently longer. The peridium of *R. atlanticus* is similar to that of *R. truncatus* but is much thicker.

Doubtful Species of *Rhizopogon* in the southeastern United States

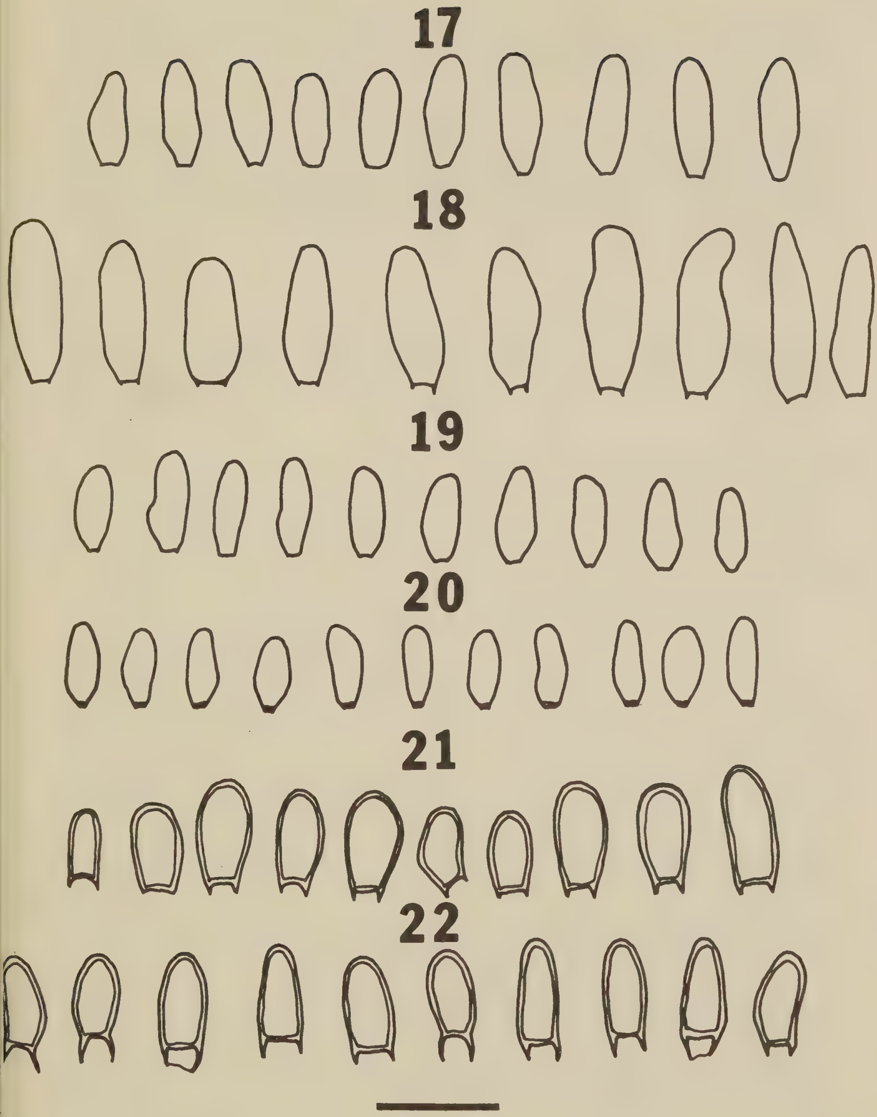
R. parasiticus Coker and Totten, Jour. Elisha Mitchell Sci. Soc. 39:101-109. The specimens at NCU (3797, 3990, 5383, 6051, 7589) and at NY (6057) are no longer in any state to be examined; they are composed solely of soil and root fragments. From the original description, however, these are nothing more than large tuberculate ectomycorrhizae common throughout the southeastern United States. I have found senescent forms of these ectomycorrhizae late in the season that are internally parasitized by different corticioid basidiomycetes. I believe that the spores found by Coker and Totten are those of a parasite, not of a parasitizing *Rhizopogon* species.

R. roseolus (Corda) Hollos, in Coker and Couch, Gasteromycetes of Eastern United States and Canada, p. 32-33. Only two collections originally cited by Coker and Couch under this name could be located at NCU, 7212 and 7214. Collections 7207 and 7229 could not be found. Both collections 7212 and 7214 are young specimens of *R. rubescens* (Tul.) Tulasne.

R. maculatus Zeller and Dodge, in Coker and Couch, Gasteromycetes of eastern United States and Canada, p. 35. Collection 955 (NCU), which was included



Figs. 11-16. Spore morphology for *Rhizopogon* spp. from the southeastern United States. Bar = 10 µm. 11. *R. nigrescens*. 12. *R. fuscorubens*. 13. *R. succosus*. 14. *R. fabri*. 15. *R. rubescens*. 16. *R. subaustralis*.



Figs. 17-22. Spore morphology for *Rhizopogon* spp. from the southeastern United States. Bar = 10 µm. 17. *R. vulgaris*. 18. *R. abietis*. 19. *R. couchii*. 10. *R. evadens* var. *evadens*. 21. *R. truncatus*. 22. *R. atlanticus*.

by Coker and Couch under this name, could not be located. I am inclined to believe that this species does not occur in our area and that another fungus, possibly *R. vulgaris*, is the one described by Coker and Couch.

R. hesleri Dodge, "Checklist of Fungi of the Great Smoky Mtns. Nat. Park," Management Report no. 29, p. 95. I find no validly published *Rhizopogon* by this name. Collection 6609 (TENN), rightly identified by Dr. Smith as *R. vulgaris*, contains a note from Dodge indicating that he was designating it as the type of *R. hesleri*. Likewise, collection 4860 (TENN), a collection of *R. couchii*, contains an annotation from Dodge identifying it as *R. hesleri*.

ACKNOWLEDGMENTS

The work presented in this study would not have been possible without the tremendous contributions of Dr. Alexander Smith, to whom I am dedicating this paper. Thanks also to Drs. James Trappe and David Hosford for their constructive comments on this manuscript.

LITERATURE CITED

Coker, W. C., and J. N. Couch. 1928. The Gasteromycetes of the Eastern United States and Canada. Univ. N. Carolina Press, Chapel Hill, N. Carolina.201 p.

Hosford, D. R. 1975. Taxonomic studies on the genus *Rhizopogon* I. Two new species from the Pacific northwest. Nova Hedwigia 51: 163-169.

_____, and J. M. Trappe. 1980. Taxonomic studies in the genus *Rhizopogon*. II. Notes and new records of species from Mexico and Caribbean countries. Bol. Soc. Mex. Mic. 14: 3-15.

Kornerup, A., and J. H. Wanscher. 1981. Methuen Handbook of Colour. 3rd ed. Eyre Methuen, London, 252 p.

Lanjouw, J., and F. A. Stafleu. 1964. Index Herbariorum part I. The Herbaria of the World. Regnum Vegetabile 31: 1-251.

Linder, D. H. 1924. A new species of *Rhizopogon* from New Hampshire. Rhodora 26: 196-197.

Smith, A. H., and S. M. Zeller. 1966. A preliminary account of the North American species of *Rhizopogon*. Mem. N.Y. Bot. Gard. 14: 1-178.

Svrcek, M. 1958. *Rhizopogon*. In Flora CSR I. Gasteromycetes, A. Pilat et al., eds, Praha.

Trappe, J. M. 1975. A revision of the genus *Alpova* with notes on *Rhizopogon* and the Melanogastraceae. Nova Hedwigia 51: 279-309.

Tulasne, L. R., and C. Tulasne. 1844. Fungi nonnulli Hypogaei, Nowi vel minus cogniti. Parlatore, Giorn. Bot. Ital. 2: 58.

Zeller, S. M., and C. W. Dodge. 1918. *Rhizopogon* in North America. Ann. Mo. Bot. Gard. 5: 1-36.

MYCOTAXON

Vol. XXVII, pp. 219-235 October-December 1986

SPECIES OF *SCUTELLOSPORA* (ENDOGONACEAE) WITH SMOOTH-WALLED SPORES FROM MARITIME SAND DUNES: TWO NEW SPECIES AND A REDESCRIPTION OF THE SPORES OF *SCUTELLOSPORA PELLUCIDA* AND *SCUTELLOSPORA CALOSPORA*

R. E. KOSKE

Department of Botany, University of Rhode Island, Kingston,
Rhode Island 02881, USA

and

CHRISTOPHER WALKER

Forestry Commission, Northern Research Station, Roslin, Midlothian, EH25 9SY,
UK

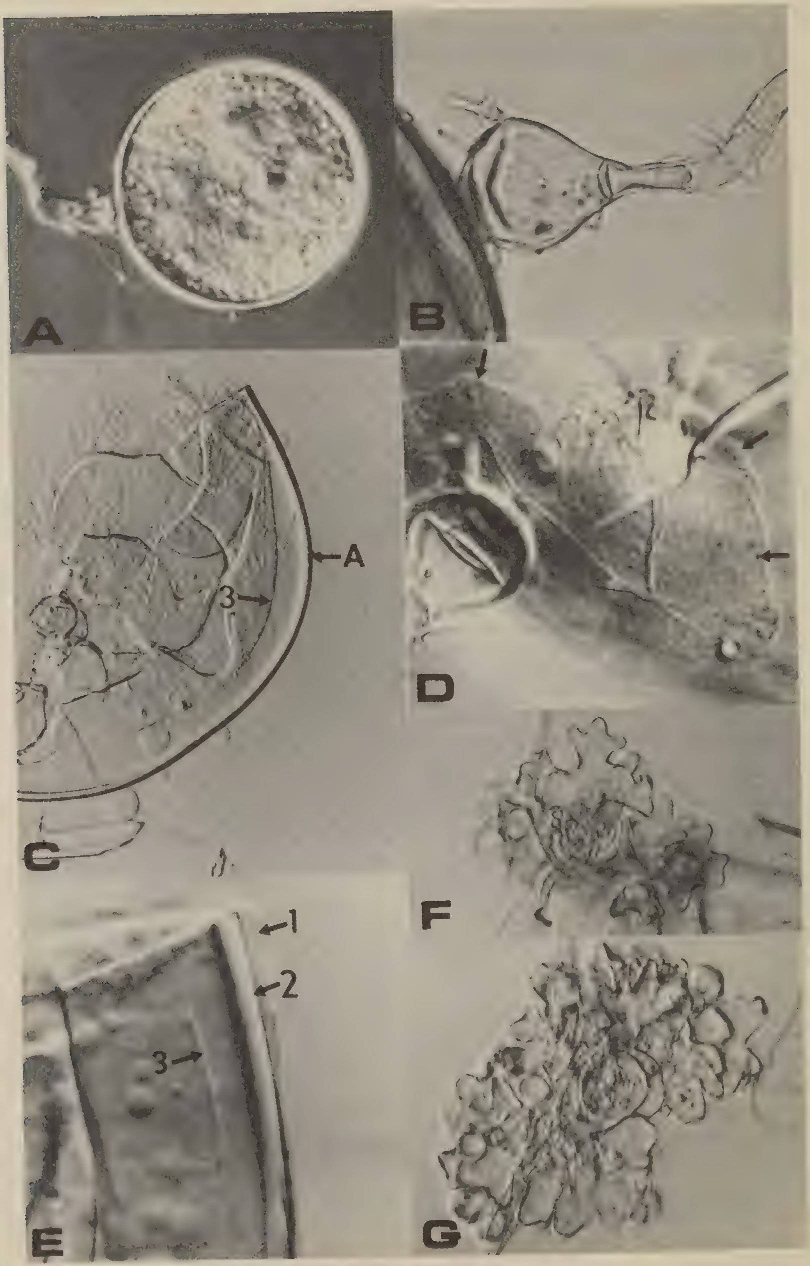
SUMMARY

Examination of soil samples from sand dunes on the eastern seaboard of the USA revealed two undescribed species of *Scutellospora* with smooth outer walls. *Scutellospora weresubiae* is characterized by its translucent pink spores with a complex wall structure, and *S. fulgida* produces hyaline spores with three walls. The species are described in this paper, and comparisons drawn with two other similar smooth-walled species, *S. pellucida* and *S. calospora*, which are illustrated and redescribed with a standardized wall terminology.

A survey of the vesicular-arbuscular mycorrhizal (VAM) fungi associated with the principal dune-colonizing plants of the east coast of the United States revealed two undescribed species of *Scutellospora* Walker & Sanders with smooth outer walls. The recent recognition of the taxonomic significance of the details of spore wall structure in the Endogonaceae prompted us to re-examine other species of *Scutellospora* with smooth-walled spores for comparison with the new species. We redescribe the spores of two previously described species, applying a standardized wall nomenclature.

MATERIALS AND METHODS

Spores were recovered from dune samples by a wet-sieving and filtration technique (Koske and Walker 1984). Specimens were mounted on microscope slides in a polyvinyl alcohol mountant with (PVL) or without (PVLG) lactophenol (Koske & Tessier 1983; Walker 1979), or, in the case of those type specimens preserved in lactophenol (*S. calospora* (Nicol. & Gerd.) Walker & Sanders and *S. pellucida* (Nicol. & Schenck) Walker & Sanders), in PVL, PVLG or lactophenol. Because parasitism by soil micro-organisms destroys inner wall structures, only apparently healthy spores were described. Collection numbers in descriptions, preceded by 'Koske' refer to soil sample collections and those preceded by 'Walker' to herbarium accession numbers. Type material was kindly loaned to us by the curator of the Farlow Herbarium.


A
B
A
3
C
D
F
1
2
3
E
G

Wall descriptions and terminology are according to Walker (1983, 1985) and Morton (1986a). Although the details of wall structure described in this study can be observed by brightfield illumination with a good-quality microscope properly illuminated and adjusted, the smaller features are more easily observed with differential-interference contrast (Nomarski) techniques. Colors are designated where possible by the color chart published by the Royal Botanic Garden, Edinburgh (Anon 1969).

Holotypes have been deposited in the herbarium at Oregon State University (OSC). Isotypes have been placed in the Farlow Herbarium (FH), and at Kew (K).

RESULTS AND DISCUSSION

SCUTELLOSPORA FULGIDA Koske et Walker sp. nov. Figs. 1A-G & 5

Sporae in solo singillatim efformatae, globosae vel subglobosae, 160-240 x 160-245 μm, lucentes, hyalinae vel straminellae. Tunicae sporae stratis tribus in termis duabus. Turma externa stratis duobus: stratum extimum laeve, fragile, hyalinum, usque ad 1 μm crassum; stratum internum lamellatum, hyalinum, ad stratum externum arcte haerens, 6-8 μm crassum, in solutione Melzeri pallide aurantiascens. Turma interna strato uno, hyalino, membranaceo, 0.5-1 μm crasso. Cellula suspensoriformis hepatica, distincte fuscior quam spora, 26-46 μm lata, tunica 1-2(-2.5) μm crassa. Cellulae auxiliares nodosae 6-10 in fasciculo, hyalinae vel pallide hepaticae, irregulares, 20-25 x 25-37 μm, prominentiis plerumque truncatis, conicis, vel subcylindricis, nodosis, 2-10 x 2-10 μm.

Spores formed singly in the soil, terminally on a bulbous suspensor-like cell; glistening, hyaline to pale straw or pale yellowish-cream; globose to subglobose; 160-240 x 160-245 μm.

Spore wall structure (see murograph, Fig. 5) of three walls (walls 1-3) in two groups (groups A and B). *Group A* with an outer smooth, brittle, hyaline unit wall (wall 1) up to 1 μm thick, tightly adherent to an inner, brittle, hyaline, laminated wall (wall 2) 6-8 μm thick. Group B of a single, thin (0.5-1 μm), membranous wall enclosing the spore contents. Wall 2 turning pale orange in Melzer's reagent, other walls not reacting.

Germination shield oval, 40-90 x 80-130 μm formed by the membranous wall.

Suspensor-like cells borne terminally on a sparsely septate subtending hypha; 26-46 μm broad, yellow-brown, distinctly darker in color than the spore, with walls 1-2(-2.5) μm thick, bearing one to several stout projections 6-38 x 2-12 μm.

Fig. 1: *Scutellospora fulgida.*

A. Whole spore, x 200.

B. Suspensor-like cell with hyphal projections, x 500.

C. Crushed spore. Wall 3 (arrow) has separated from wall group A, x 160.

D. Germination shield. Margin is indicated by arrows, x 485.

E. Wall structure of a crushed spore. Wall one has fractured and folded back from wall 2. Wall 3 is indicated, x 1235.

F. Auxiliary cells, x 620.

G. Cluster of auxiliary cells, x 520.

Auxiliary cells in soil borne on coiled, hyaline hyphae 4-5 μm diameter in clusters of 6-10(-20), hyaline to pale yellow-brown, irregularly shaped, 20-25 x 25-37 μm, with broad, usually truncated, conical to subcylindric knobby projection 2-10 x 2-10 μm.

DISTRIBUTION AND HABITAT: Known only from a limited area of coastal sand dunes on the eastern North American seaboard. *Scutellospora fulgida* occurred frequently in samples taken from maritime dunes at the southern tip of New Jersey and farther south to Maryland and Virginia. However, it was not recovered from any of more than 500 samples collected from mid New Jersey to as far north as Maine.

MYCORRHIZAL ASSOCIATIONS: Found in the root zones of *Ammophila breviligulata* Fern., *Solidago sempervirens* L., and *Uniola paniculata* L., but not proven mycorrhizal.

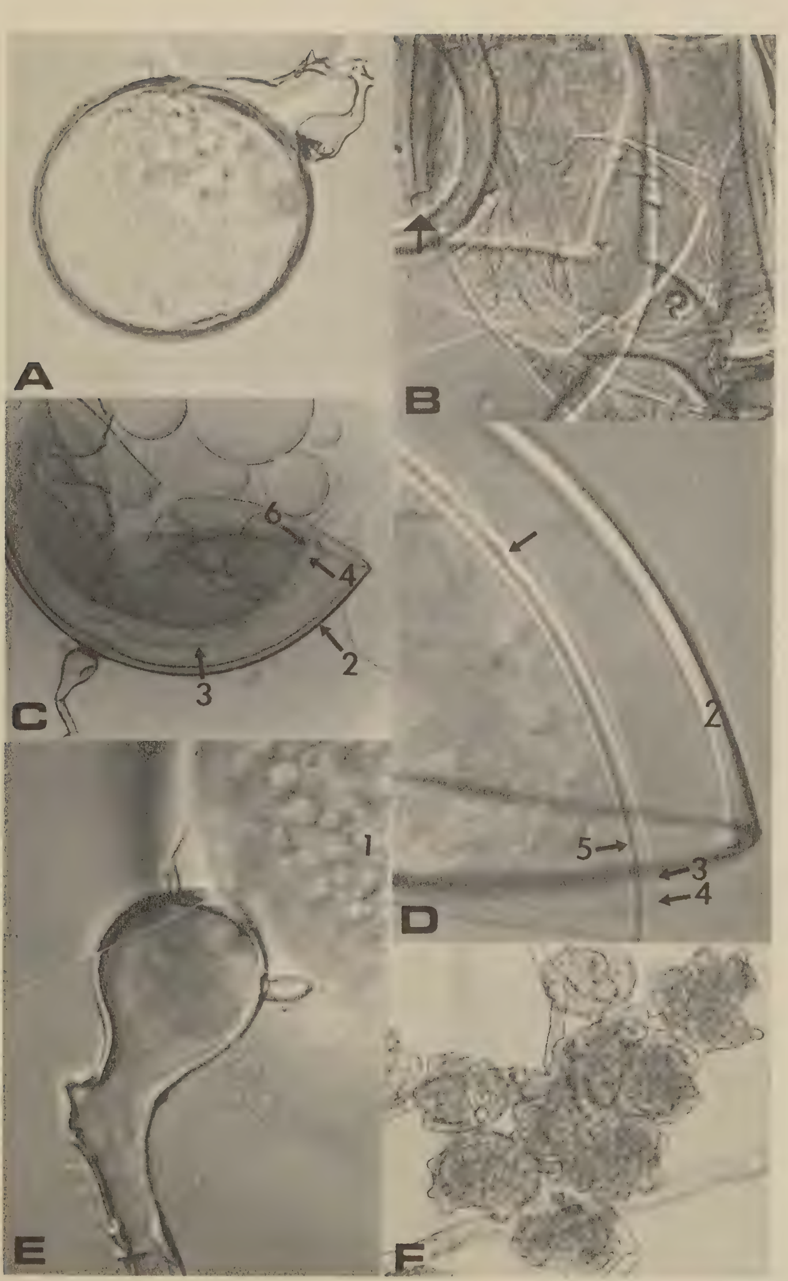
ETYMOLOGY: Latin, *fulgida*, (shining, gleaming, glittering), referring to the appearance of the spores when viewed through the dissecting microscope.

COLLECTIONS EXAMINED: HOLOTYPE: VIRGINIA - Virginia Beach Township, Seashore State Park, among roots of *A. breviligulata* on sand dunes (Koske 505; Walker 658; 23 April 1983). *Other Collections*; NEW JERSEY - Cape May Co., Cape May Point Sand Dunes (Koske 401, 404; 14 March 1982); VIRGINIA - Accomack Co., Assateague Island Sand Dunes (Koske 437, 440, 445, 457; 15 March 1982).

Wall 1 of *Scutellospora fulgida* is usually easy to observe in crushed spores (Fig. 1F), but in some specimens it is thin and difficult to see, even under high magnification. Wall 3 also can be difficult to detect as it may be tightly adherent to wall 2.

Scutellospora fulgida differs from other species mainly by its hyaline spores and relatively simple wall structure. It most resembles *S. pellucida* or hyaline specimens of *S. calospora* when viewed with a dissecting microscope. The inner wall group (group B) of *S. fulgida* spores is thin, consisting of a single membranous wall (Figs. 1C, F). The formation of the germination shield in spores of *S. fulgida* may lead to the erroneous impression that group B has two walls. The inner wall group of *S. calospora* consists of two juxtaposed membranous walls (Figs. 4D, F), while that of *S. pellucida* consists of three walls (Fig. 3G). In addition, the innermost wall of both *S. calospora* and *S. pellucida* spores becomes red or reddish-purple in Melzer's reagent, while that of *S. fulgida* stains yellow. Spores of all three of these species possess a thin outermost unit wall. Spores of *S. fulgida* develop a pale yellow coloration in the walls upon storage in polyvinyl alcohol mountants and thus may be confused with colored spores of *S. calospora*, but the different wall structures and the formation of clustered auxiliary cells in the former (Figs. 1E, G) compared to single auxiliary cells in the latter (Figs. 4H, I) serve to separate the species under such circumstances.

Scutellospora fulgida could, on examination under a dissecting microscope, also be mistaken for *S. gilmorei* (Trappe & Gerd.) Walker and Sanders, another hyaline-spored species. Examination of mounted specimens through a compound microscope reveals, however, that although spores of the latter possess an outer wall group similar to *S. fulgida*, their inner wall group is composed of four easily separable walls rather than a single membranous wall.


A
B
2
C
6
4
2
3
D
2
5
3
4
E
1
F

Another hyaline-spored species, *S. savannicola* (Ferr. & Herr.) Walker & Sanders, has been described from Cuba. We have been unable to obtain specimens of the type material to examine, but the published description (Ferrer and Herrera 1981) is of a spore with five walls in three groups, an outer wall group composed of two walls up to 3 μm and 2.3 μm thick, respectively, a middle wall group of two membranous walls, 1.5 and 1.3 μm thick, respectively, and an inner wall 1 μm thick.

SCUTELLOSPORA WERESUBIAE Koske et Walker sp. nov. Figs. 2A-F & 5

Sporae in solo singillatim efformatae, globosae, subglobosae vel irregulares, 125-265 x 135-414 μm, lucentes, pallide vel saturate incarnatae. Tunicae sporae stratis sex in turmis trilus. Turma externa stratis duobus: stratum eximum laeve, fragile, hyalinum, usque ad 0.5 μm crassum, adstratum internum, fragile, incarnatum, 3-8.8 μm crassum, in solutione Melzeri interdum rubescens haerens. Turma media stratis duobus membranaceis, utrumque usque ad 1 μm crasso. Turma interna strato extimo coriaceo, hyalino, 2-8 μm crasso, stratum membranaceum, hyalinum, 0.5 μm crassum, in solutione Melzeri rubescens, cingenti. Cellula suspensoriformis hyalina vel pallide testacea, 32-50 μm lata, tunica distaliter 1 μm crassa, prope sporam usque ad 5 μm. Cellulae auxiliares nodosae 5-14 in fasciculo, incarnatae vel pallide brunneo, subglobosae, 17-33 x 25-40 μm, prominentiis plerumque truncatis, conicis nodosis, 4-7 x 7-14 μm.

Spores formed singly in the soil terminally on a bulbous suspensor-like cell; translucent, glistening, pale pink to deep pink; globose to subglobose or irregular; 125-265 x 135-414 (mean 210 x 210) μm.

Spore wall structure (see murograph, Fig. 5) of six walls (walls 1-6) in three groups (groups A, B and C). *Group A* often with an outer, smooth, brittle, hyaline, unit wall (wall 1) up to 0.5 μm thick tightly adherent to an inner brittle, pink, laminated wall (wall 2) 3-8.8(-15) μm thick that sometimes turns red in Melzer's reagent.

Group B of two membranous walls (walls 3 and 4), each up to 1 μm thick, wrinkled in crushed spores.

Group C formed by a thick hyaline coriaceous wall (wall 5) (2-8 μm thick) surrounding a hyaline membranous innermost wall (wall 6) 0.5 μm thick that turns red in Melzer's reagent.

Germination shield, known only from two specimens, cardioid, 100 x 69-80 μm with a smooth margin 1 μm thick and with a germ tube initial in each lobe.

Suspensor-like cells borne terminally on a sparsely septate or aseptate subtending hypha, 32-50 μm broad, hyaline to pale brownish-yellow, with walls 1 μm thick

Fig. 2. *Scutellospora weresubiae.*

A. Whole spore, x 140.

B. Germination shield with germ tube initial (arrow), x 365.

C. Crushed spore in Melzer's reagent. Wall 6 is darkly stained. Wall 5 is not visible in this photograph. Walls 3 and 4 are wrinkled, x 125.

D. Wall structure. Walls one and 6 are not easily visible in this photograph. Walls 3 and 4 are closely associated. Note wrinkling of wall 3 (arrow) x 365.

E. Composite photograph of suspensor-like cell with hypal pegs, x 495.

F. Auxiliary cells, x 480.

distally, thickening to 5 μm at the spore base. One or two hyphal pegs up to 27 μm long x 3-8 μm wide may arise from the suspensor-like cell and project towards the spore base. Pegs not occurring on all specimens.

Auxiliary cells in soil borne in clusters of 5-14, bright pink when fresh, fading to pale brown; subglobose, 17-33 x 25-40 μm, with blunt, rounded knobby projections 3-6 x 4-7 μm or broad truncated conical projections 4-7 x 7-14 μm; produced on coiled pink hyphae 3-4 μm diameter.

DISTRIBUTION AND HABITAT: Known only from coastal sand dunes in Virginia, Florida and South Carolina, and from sandy spoil heaps of a copper mine in Malaysia.

At first we thought *S. weresubiae* to be limited in its distribution to an area stretching from the south end of the Assateague Island, southward to South Carolina. Searching for the species among 21 samples from the north end of the 60 km-long island, from 41 samples among dunes in New Jersey and from more than 400 samples from dunes of the Rhode Island and Massachusetts coast, proved fruitless, despite the fact that the vegetation and edaphic conditions in all these areas are similar. However, the species later was identified from collections in Florida (D. Sylvia, pers. comm.) and from Malaysia (G. Sankaralingam, pers. comm.). Both these last collections were from sand, and it seems that the species is climatically and edaphically controlled and might be expected to occur in sandy conditions in relatively warm areas.

MYCORRHIZAL ASSOCIATIONS: *Scutellospora weresubiae* was found in association with field-grown plants of *Ammophila breviligulata, Uniola paniculata*, and *Solidago sempervirens*, but failed to form mycorrhizae in pot culture with onion (*Allium cepa* L. cv Agway Sweet Spanish), clover (*Trifolium repens* L.), and corn (*Zea mays* L. cv Seneca).

ETYMOLOGY: Named in honor of Luella K. Weresub, distinguished mycologist.

COLLECTIONS EXAMINED: HOLOTYPE: VIRGINIA - Accomack Co., Assateague Island sand dunes from underneath *Solidago sempervirens* (Koske 440, Walker 636; 15 March 1982). *Other collections*: VIRGINIA -Accomack Co., Assateague Island (Koske 438, 439, 445, 459; 15 March 1982), (Koske 294; 20 April 1981); Virginia Beach Township, Seashore State Park (Koske 502, 506, 522, 526; 23 March 1983); SOUTH CAROLINA - Horry Co., Myrtle Beach (Koske 288; 14 April 1981).

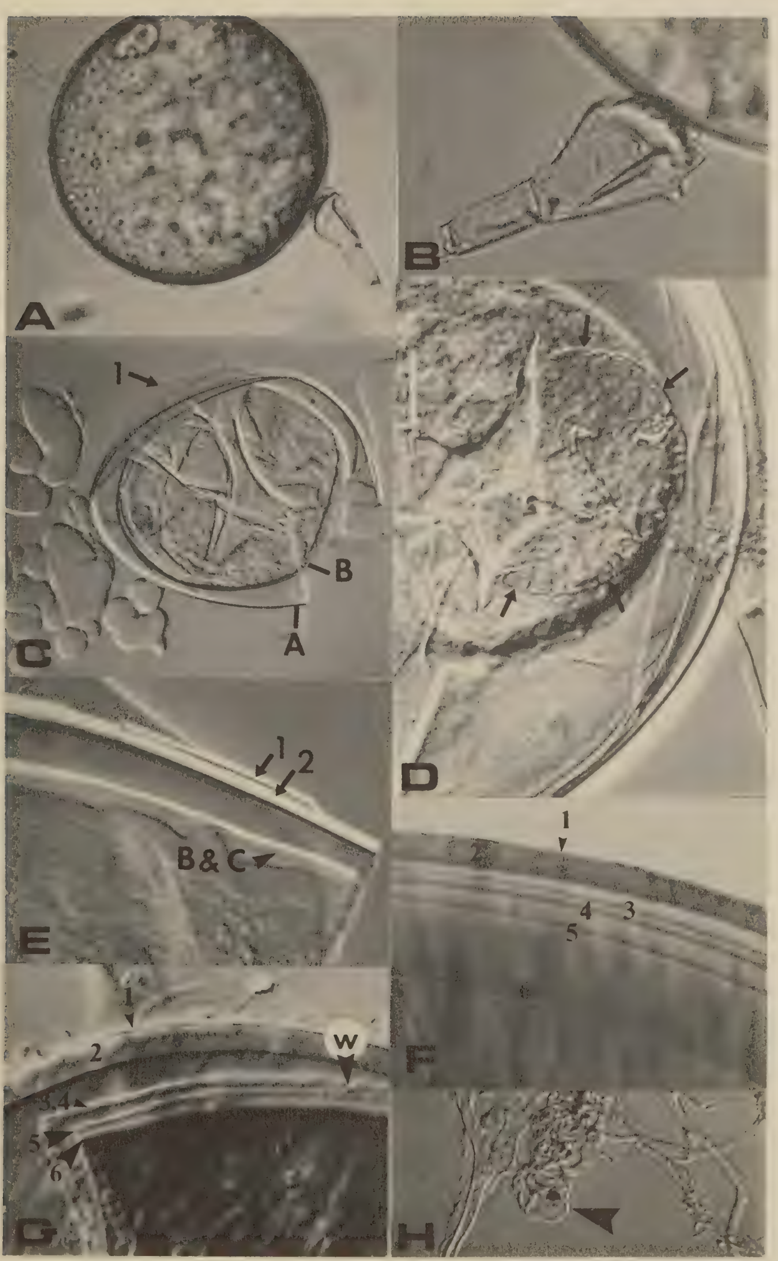
The complex wall structure and pink color of *S. weresubiae* spores distinguish them from other species. The outermost wall (wall 1) may be difficult to observe, and can best be seen on specimens that have been vigorously crushed. The pink wall (wall 2) loses its color almost immediately when spores are placed in lactophenol, formalin, or polyvinyl alcohol, although it is retained for a few days in glycerol jelly mounts. In fresh specimens, wall 6 quickly stains dark red in Melzer's reagent. Wall 2 usually stains red also, but only after a longer time. Occasionally spores possess one or two laminae broken loose from wall 2. These may be misleading, appearing as additional unit walls between walls 2 and 3. The walls of the inner wall group may best be observed by allowing crushed spores to stain in Melzer's reagent for about 15 minutes and then adding a polyvinyl alcohol mounting solution to the edge of the coverslip and allowing it to infiltrate overnight or by crushing spores in PVL or PVLG to which has been added a drop of freshly prepared Melzer's reagent. The inner wall group is difficult to interpret. In wall group B, walls 3 and 4 loosely surround walls 5 and 6 of group C and frequently are noticeably wrinkled (Figs. 2C, D). Wall 3 is thin (<0.2 μm) and may seem absent from some spores. It is, however, probably present in all spores, but may be so thin that it cannot be resolved by light microscopy. Studies of cracked spores by scanning electron microscopy confirmed the presence of this wall on all specimens examined, along with the other walls observed by light microscopy. Spores fixed in formaldehyde often show wall 3 and 4 associated with wall group A. In unfixed specimens they are usually close to walls 5 and 6 in Group C. We therefore placed them in a group of their own to avoid confusion. Wall 5 stains yellow in Melzer's reagent and is pliable, although up to 8 μm thick. Wall 6 is best seen by its strong reaction to Melzer's reagent, this wall and wall 3 often being extremely difficult to observe if unstained.

The color of *S. weresubiae* spores fades with age, and many older specimens retain only a faint pink tinge. The bright pink color of fresh spores was not reduced by immersion for several days in phosphate buffer at pH 4 or pH 10. In water, the color pales considerably after a day or two, though it usually still can be detected when the spores are observed with a mixture of transmitted and reflected light. Spores of *S. weresubiae*, incubated on filter paper placed on moist sand, germinated after two weeks to produce bright pink germ tubes, hyphae, and auxiliary cells. In preservative, such as formaldehyde, gluteraldehyde, formalin-acetic acid, or lactophenol, the color is lost very rapidly. Thus, it is important that the color of spores is recorded when they are freshly extracted from the soil.

S. weresubiae resembles *S. alborosea* (Ferr. & Herr.) Walker & Sanders, a pink-spored species reported only from Cuba, although the wall structure of the two species seemingly differs substantially. Whereas the former has spores with six walls in three groups, the latter is described as having only two wall groups, the outer group with only two walls and the inner with a single membranous wall. We have unfortunately been unsuccessful in obtaining material of *S. alborosea* for examination and have thus had to make this comparison from the description in the protologue.

The only other pink-spored species in the Endogonaceae is *Gigaspora rosea* Nicol. & Schenck. Spores of this species are opaque and creamy-white with a coral-pink coloration near the suspensor-like cell. They are not translucent and do not have the overall bright pink color of spores of *S. weresubiae*. In addition, spores of *G. rosea* have the simple wall structure, direct germination characteristics and echinulate auxiliary cells that distinguish *Gigaspora* spp. from species of *Scutellospora* (Walker & Sanders 1986).

Very lightly pigmented or faded spores of *S. weresubiae* resemble those of *S. pellucida*, and spores of both species have six walls in three groups. Wall 1 in both is a unit wall, closely appressed to the laminated second wall, but wall 1 of the former is thin (up to 0.5 μm) and often extremely difficult to see, whereas the corresponding wall of the latter is relatively thick (1-2 μm) in most specimens and can normally be seen


A
B
1
B
A
C
D
1
2
B & C
E
1
2
4
3
5
F
1
2
W
3,4
5
6
G
H

clearly at 400 x magnification (Figs. 3C, E). The structure of the inner wall groups (Group B and C) of the two species may appear similar at low magnification. However, wall group B of *S. pellucida* consists of a very thin membranous wall and two unit walls, with the membranous wall closely adherent to one of the unit walls (Figs. 3F, G). In *S. weresubiae*, wall group B is comprised of two membranous walls (Figs. 2C, D), each usually thicker than the membranous wall of *S. pellucida*. *Group C* of *S. pellucida* is an amorphous wall (Figs. 3F, G) that has plastic properties in PVL and PVLG (see *S. pellucida* discussion) and stains reddish-purple in Melzer's reagent. Wall group C of .S. weresubiae is formed by a thick, coriaceous wall and a thin, membranous innermost wall (Figs. 2C, D) that stains red (but not reddish-purple) in Melzer's reagent. The taxonomic significance of such staining differences in some Endogonacea has been discussed by Morton (1986b).

The differences in wall structure of *S. weresubiae* and *S. pellucida* can be compared in the murographs (Fig. 5).

REDESCRIPTION OF *SCUTELLOSPORA PELLUCIDA* AND *S. CALOSPORA*

In comparing the newly described species of *Scutellospora* with other smooth-walled species, it became clear that a redescription of spores of certain existing taxa making use of the standardized wall terminology suggested by Walker (1983), may be helpful. The following descriptions of the spores of *S. pellucida*. and *S. calospora* are based upon examination both of type specimens and other collections. Specimens of *S. pellucida* from sand dunes in Virginia (Koske 518) were up to 250 x 410 μm; somewhat larger than originally described, but we consider this to be intraspecific variation. The size range of *S. calospora* has also been increased from measurements of several collections.

SCUTELLOSPORA PELLUCIDA (Nicol. & Schenck) Walker & Sanders
Figs. 3A-H & 5

Spores formed singly in the soil or in roots, borne terminally on a bulbous suspensor-like cell; glistening with oil droplets, hyaline to pale grey, globose, ellipsoid, or irregular; 58-183(-250) x 58-241(-410) μm.

Fig. 3: *Scutellospora pellucida.*

A. Whole spore, x 235.

B. Suspensor-like cell, x 570.

C. Crushed spore showing wall groups A and B. Wall one (arrow) has separated from wall 2, x 140.

D. Germination shield. Margin (arrow) with invaginations, x 235.

E. Wall structure of spore preserved in formalin. Note walls 1 and 2, and fused walls of group B, x 935.

F. Wall structure of fresh spore in PVLG. Wall one is just visible (arrow). Note separation of wall 6 from other walls, x 1310.

G. Wall structure of fresh spore crushed in Melzer's reagent. Walls 3 and 4, typically, are closely adherent in this spore. Wrinkling of wall 3 is indicated (W). Note dark staining of wall 6, x 870.

H. Auxiliary cells, x 350.

Spore wall structure (see murograph, Fig. 5) of six walls (walls 1-6) in three groups (groups A, B and C). *Group A* with an outer smooth, brittle, hyaline, unit wall (wall 1) 1-2 μm thick, closely appressed to an inner brittle, hyaline, laminated wall (wall 2) 2-7 (-18) μm thick. *Group B* consisting of a hyaline membranous wall (wall 3) (1 μm thick) closely adherent to two hyaline unit walls (walls 4 and 5). Wall 4, 1-2 μm thick; wall 5, 0.8-3 μm thick. *Group C* consisting of a single, hyaline amorphous wall (wall 6), 2-5 μm thick when measured in Melzer's reagent, of variable thickness in PVL or PVLG (see below). Walls 2 and 5 typically stain reddish-purple in Melzer's reagent, although wall 2 remains unstained in some specimens.

Germination shield oval, 110-140 x 125-160 μm, the margin with invaginations.

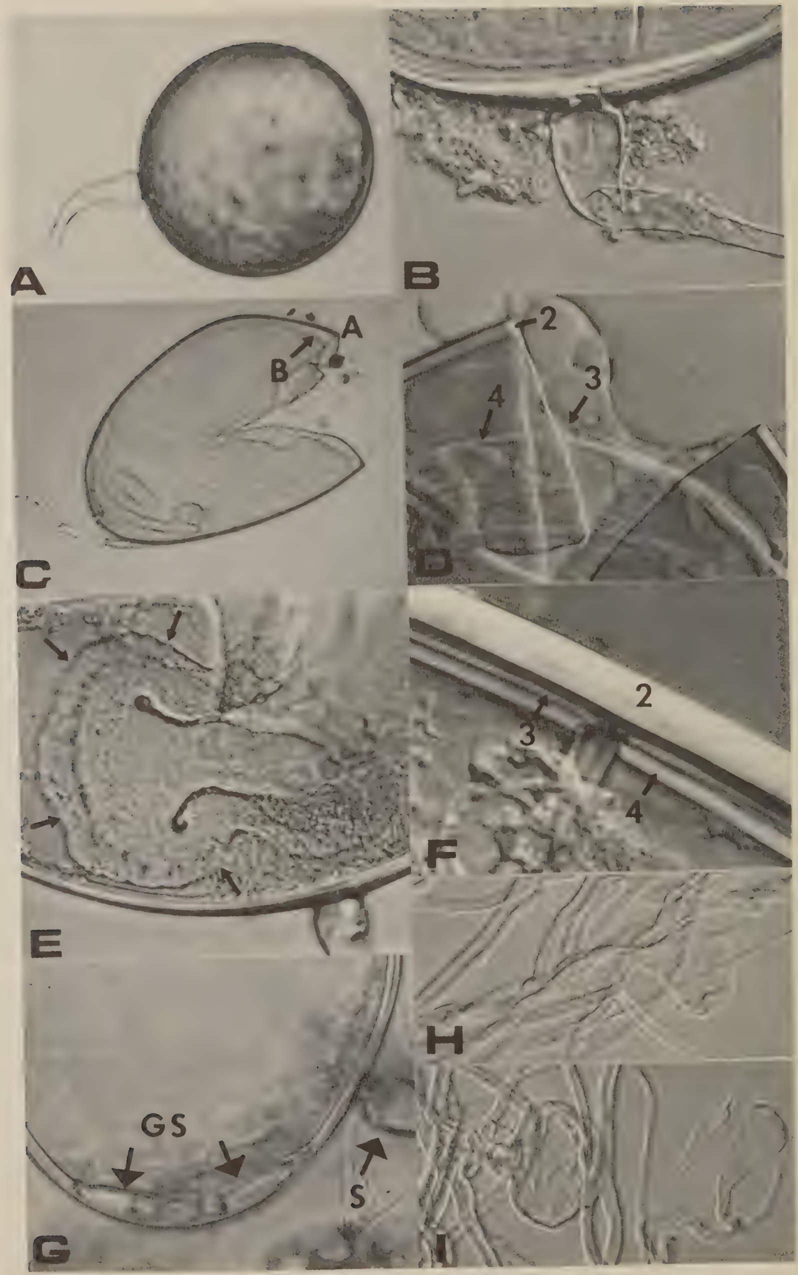
Suspensor-like cell borne terminally on a septate subtending hypha; 10-29(-50) μm broad, hyaline; walls <0.5 μm thick distally, thickening to 2.5 μm near the spore base.

COLLECTIONS EXAMINED: USA: FLORIDA - Jay (Isotype in FH); CALIFORNIA - Santa Barbara Co., San Miguel Island Dunes (Koske 561, 567-570, 572, 575, 576, 588; 5 July 1984); MASSACHUSETTS - Bristol Co., S. Dartmouth Dunes (Gemma 2-20-6; February 1985); NEW JERSEY - Cape May Co., Cape May Pt. Dunes (Koske 401, 407, Walker 519; 14 March 1982); Ocean Co., Ocean City Dunes (Koske 382; 13 March 1982); RHODE ISLAND - Washington Co., Moonstone Beach Dunes (Friese P3, Koske A7; 6 August 1983); SOUTH CAROLINA - Horry Co., Myrtle Beach Dunes (Koske 288; 14 April 1981); VIRGINIA - Virginia Beach Township, Seashore State Park Dunes (Koske 505, 518, 520, 23 April 1983); WEST VIRGINIA - Preston Co., pot culture from mine site (Morton 396, Koske A8).

The outermost unit wall (wall 1) of *S. pellucida* was easily resolved in most specimens, sometimes separating distinctly from wall 2 (Figs. 3C, E), though in some specimens it was not clearly distinguishable (Figs. 3G, H). The laminated wall (wall 2) of spores of *S. pellucida* typically is 2-7 μm thick, but in a few spores from high-aluminum, low-pH sites in West Virginia, this wall reached a thickness of up to 18 μm. Dimensions of other walls in these samples matched those of more typical specimens.

The inner wall groups (B and C) of *S. pellucida* can be very difficult to interpret, especially at lower magnifications when they may appear as a single, hyaline, flexible wall 1.5-5 μm thick with 2-4 apparent laminations. The appearance and thickness of the walls in groups B and C depends upon the state of the spores when the slide was made (fresh or preserved), the mounting medium, and how the spores were crushed (once or twice). When fresh spores are crushed in Melzer's reagent, wall 6 stains dark reddish-purple within a minute, and walls 3-5, which remain unstained, can often be distinguished (Fig. 3G). Frequently, however, wall 3 is so closely appressed to wall 4 that often it is detectable only by the fine wrinkling it exhibits (Fig. 3G). In some specimens, walls 3-5 remain so close together that they appear as a single wall.

When spores preserved in 5% formaldehyde for more than a few months were crushed in Melzer's reagent, the distinctive staining reactions of walls 2 and 6 did not occur. Wall 2 became reddish-brown, and wall 6 did not stain. A similar lack of staining in Melzer's reagent following preservation occurs in spore walls of several species of *Acaulospora* (Morton 1986b). A second change that occurred when spores of *S. pellucia* were preserved was the fusion of walls 3-6 to form a single, thick, apparently laminated wall (Fig. 3E).


A
B
A
B
C
2
3
4
D
E
2
3
4
F
GS
S
G
H
I

Fresh spores of *S. pellucida* mounted in PVL or PVLG and crushed once exhibit a wall structure generally similar to that of spores mounted in Melzer's reagent (Fig. 3F). Wall 6 may appear slightly wrinkled in some spores that have been so treated. If, after a few minutes, pressure is again applied to the coverslip, the amorphous nature of wall 6 becomes apparent, and the wall becomes coarsely wrinkled. The interval between crushings apparently allows the PVL or PVLG to interact with the wall, giving it a plastic consistency (Morton 1986a, b). If sufficient force is applied, wall 6 may deform markedly and extrude completely from wall group B. The amorphous innermost wall of spores of some *Acaulospora* species may be similarly extruded when spores are crushed (Morton 1986a). The thickness of wall 6 when measured after the second crushing thus is dependent upon the pressure exerted during that crushing. For this reason, the thickness range given for this wall (2-5 μm) is based on specimens mounted in Melzer's reagent which does not induce the plasticity. The amorphous wall type, its staining reactions and other characteristics were originally defined and described by Morton (1986a, b) for a species of *Acaulospora*.

The variable appearance of wall 6 as influenced by slide preparation techniques and freshness of the spores, and the difficulty in resolving the 3 walls of group B make *S. pellucida* one of the most difficult species to identify.

SCUTELLOSPORA CALOSPORA (Nicol. & Gerd.) Walker & Sanders
Figs. 4A-I & 5

Spores formed singly in the soil, terminally on a bulbous suspensor-like cell; translucent, hyaline to pale greenish-yellow; globose, ellipsoidal or cylindrical, occasionally broader than long; 114-285(-511) x 110-412(-511) μm.

Spore wall structure (see murograph, Fig. 5) of four walls (walls 1-4) in two groups (groups A and B). *Group A* consisting of an inner, brittle, hyaline to pale yellow, very finely laminated wall (wall 2) 3-5 μm thick that may be surrounded by a thin, very closely appressed hyaline unit wall (wall 1), 0.5-1 μm thick. *Group B* of two hyaline membranous walls (walls 3 and 4). Wall 3, 0.5-1 μm thick, often wrinkling in crushed spores. Wall 4, 1-1.5 μm thick, staining red in Melzer's reagent.

Fig. 4: *Scutellospora calospora.*

A. Whole spore, x 200.

B. Suspensor-like cell, x 470.

C. Crushed spore showing wall groups A and B, x 115.

D. Crushed spore. Wall 3 has separated from wall 4. Wall one is not visible, x 470.

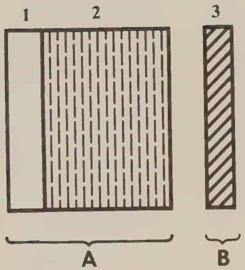
E. Germination shield in face view. Margin indicated by arrows, x 345.

F. Spore wall structure. Walls 2-4 are indicated. Note laminations in wall 2. Wall one is not apparent, x 1150.

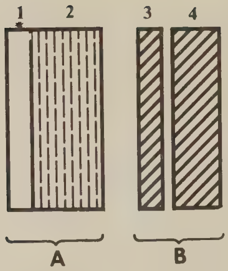
G. Germination shield, lateral view. Note location of suspensor-like cell (arrow), x 395.

H. Auxiliary cell with smooth surface, x 415.

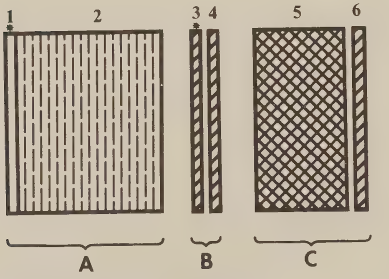
I. Auxiliary cells with knobby surface, x 415.



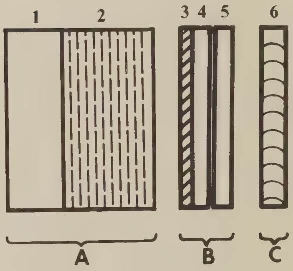
Gigaspora fulgida



Gigaspora calospora



Gigaspora weresubiae



Gigaspora pellucida

Germination shield oval, 35-70 x 50-90 μm, often with invaginations along the margin.

Suspensor-like cell borne terminally on a septate subtending hypha; 33-48 μm broad; walls concolorous with wall 2 of spore; walls 1 μm thick distally, thickening somewhat near the spore base.

COLLECTIONS EXAMINED: UK: SCOTLAND - Perthshire, East Newton (Holotype in FH); SCOTLAND - Midlothian, Northern Research Station of the Forestry Commission, in pot culture with *Trifolium repens* L. started with a single spore from a grassy verge in the grounds of the research station (Walker 1002; 13 February 1985). ENGLAND -Hertfordshire, Rothamsted Experiment Station, from a pot culture (with *Allium porrum* L.) the origins of which are unknown (Walker 1153; 22 August 1985). USA: CALIFORNIA - Santa Barbara Co., San Miguel Island Dunes (Koske 568, 581, 596; 5 July 1984); MASSACHUSETTS - Suffolk Co., Plum Island Dunes (Koske 339; 9 October 1981); NEW JERSEY -Monmouth Co., Spring Lake Dunes (Koske 361; 13 March 1982); RHODE ISLAND - Washington Co., Moonstone Beach Dunes (Koske 278; 18 February 1981: Friese 63; 8 April 1983).

The characterization of *Scutellospora calospora* is made somewhat difficult by the paucity and poor state of preservation of the type material, which consists of a few spores mounted (by Walker in 1979) in PVL and three or four spores originally preserved in lactophenol. Hall and Abbott (1984) examined this material and redescribed the species. They indicated a wall structure which, in the terminology of Walker (1983), has an outer wall group (A) consisting of a thin unit wall surrounding a laminated wall, and an inner wall group (B) of a single membranous wall. We have examined the type material and have drawn different conclusions. The outer wall often is very difficult to see in most specimens, though we agree it probably is present, and we are in complete accordance with Hall and Abbott about wall 2, a laminated wall to which wall 1 is tightly adherent. We differ in our interpretation of the inner wall group. In all the specimens we examined, we observed that wall group B consisted of two adherent membranous walls (Figs. 4D, F).

There is some confusion in the literature regarding the color of spores of *S. calospora*. In recent years, the species has been considered to have yellow or yellow-green spores, and the impression has been given that only immature spores are hyaline. Gerdemann and Trappe (1974) described the species as having 'pale yellow to greenish yellow' spores, and Trappe (1982) in his synoptic key included *S. calospora* only in the color group with 'outer wall layer yellow'. Hall and Abbott (1984) did not describe the color of the spores, but they did note that the 'middle wall layer' was 'coloured'. In a key to the species of Endogonaceae (Hall and Fish 1979), *S. calospora* was described as having 'mature spores pale yellow to pale greenish yellow', and in a later key the species was similarly included only in couplets derived from spores that are 'coloured

Fig. 5: Murographs of four species of *Scutellospora*. Shading is by vertical alternating dotted lines for laminated walls, 45° hatching in one direction for membranous walls, 45° hatching in both directions for coriaceous walls, and curved lines for 'amorphous' walls. Unit walls are left unshaded. Walls marked with an asterisk are very difficult to see.

though may be hyaline when young' (Hall 1984). The protologue of *Scutellospora calospora* describes the spores as 'colorless or light yellow' (Nicolson and Gerdemann 1968), and in a key to the Endogonaceae of Florida, Nicolson and Schenck (1979) indicate that they are 'hyaline, white or shades of yellow'.

This confusion was compounded when we isolated (in both single-spore and multi-spore pot cultures) a small spored *Scutellospora* from Scotland that had hyaline or white spores of the correct size range of *S. calospora* and possessed a wall structure exactly coinciding with our interpretation of the type material of that species (though sometimes wall 4 was extremely thin and could be detected only when fresh spores were treated with Melzer's reagent). Under storage in moist soil, or when preserved in 5% formaldehyde solution, spores from our cultures generally remained hyaline, although after a few days in water at room temperature, some of them became a little yellowish (though it should be emphasized that this coloration was extremely pale, and easily noticeable only in comparison with freshly extracted specimens). When stored in lactophenol, however, the spores quickly became yellow to yellow-olive.

To resolve these questions of spore color, we sought the advice of Dr Tom Nicolson, one of the original authorities for *Scutellospora calospora*, who kindly agreed to examine our culture material. He concluded that our collections agreed with his concept and memory of the species, and stressed that the material he described was mainly colorless, but that some specimens appeared slightly greenish-yellow. In view of this, we consider that *S. calospora* has hyaline or white to very pale greenish-yellow spores. It seems likely that dark yellow or greenish-yellow spored species that may have been attributed to *S. calospora* might more properly be placed as *S. auriglоba* (Hall) Walker and Sanders or some other taxon. Nevertheless, we are unsure as to how much significance to give to spore color as a taxonomic criterion, and if yellow spores are found that have the size range, wall structure, germination characteristics, and auxiliary cell features typical of *S. calospora*, then consideration should be given to extending the species concept to include them in that taxon, rather than to describing a new species. In view of this uncertainty, any use of isolates considered to be this fungus should be backed up by a careful description of the spores, deposition of specimens in a herbarium, and where possible, preservation of living cultures for future examination and use.

ACKNOWLEDGMENTS

We thank Dr. J. M. Trappe for preparing the Latin diagnoses, reviewing the manuscript and making useful suggestions, Dr. J. Morton for providing spores and helpful comments, R. Sheath, A. Steinman, J. Moffet and C. Friese for collecting dune samples, D. Scales for the scanning electron microscopy, US National Park Service for permission to collect samples from National Park lands, the Chief Ranger of Seashore State Park, and Don Tiller, Refuge Manager, US Fish and Wildlife Service, for permission to collect at the Moonstone Beach dunes, Rhode Island, W. L. Halvorson, Channel Islands National Park for making possible the collections from California, T. H. Nicolson for his advice, and Marion Jenkins and Shiela Swan for typing the manuscript.

LITERATURE CITED

Anon, 1969. *Flora of the British Fungi. Colour Identification Chart*. Royal Botanic Garden, Edinburgh.

Ferrer, R. L., and R. A. Herrera, 1981. El genero *Gigaspora* Gerdemann et Trappe (Endogonaceae) en Cuba. *Rev. Jardin Bot. Nacional, Habana* **1**(1):43-66.

Hall, I. R., 1984. Taxonomy of VA mycorrhizal fungi. In: *VA Mycorrhiza* (Ed. by C. L. Powel & D. J. Bagyaraj), pp. 57-95, CRC Press, Florida.

Hall, I. R. and L. K. Abbott, 1984. Some Endogonaceae from South Western Australia. *Transactions of the British Mycological Society* **83**:203-208.

Koske, R. E., and B. Tessier, 1983. A convenient, permanent slide mounting medium. *Mycological Society of America Newsletter* **34**(2):59.

Koske, R. E., and C. Walker, 1984. *Gigaspora erythropa*, a new species forming arbuscular mycorrhizae. *Mycologia* **76**: 250-255.

Morton, J. B., 1986a. Three new species of *Acaulospora* from high aluminum, low pH soils in West Virginia. *Mycologia* **78.** In press.

Morton, J. B., 1986b. Effect of mountants and fixatives on wall structure and Melzer's reaction in spores of two *Acaulospora* species (Endogonaceae). *Mycologia*. In review.

Nicolson, T. H. and Schenck, N. C., 1979. Endogonaceous mycorrhizal endophytes in Florida. *Mycologia* **71**:178-198.

Walker, C., 1979. The mycorrhizast and the herbarium: the preservation of specimens from VA mycorrhizal studies. In: *Program and Abstracts, 4th N. American Conference on Mycorrhiza*. Fort Collins, Colorado.

Walker, C., 1983. Taxonomic concepts in the Endogonaceae: spore wall characteristics in species descriptions. *Mycotaxon* **18**:443-455.

Walker, C., 1986. Taxonomic concepts in the Endogonaceae: II. A fifth morphological wall type in endogonaceous spores. *Mycotaxon* **25**:95-99.

Walker, C. and Sanders, F. E., 1986. Taxonomic concepts in the Endogonaceae: III. The separation of *Scutellospora* gen. nov. from *Gigaspora* Gerd. & Trappe. *Mycotaxon*. In Press.

MYCOTAXON

Vol. XXVII, pp. 237-245 October-December 1986

FOUR NEW EFFIGURATE-CRUSTOSE SPECIES OF *PARMELIA* (LICHENES, PARMELIACEAE) FROM SOUTHERN AFRICA

FRANKLIN A. BRUSSE

Botanical Research Institute
Private Bag X101, Pretoria,
South Africa

ABSTRACT

Four new effigurate-crustose species are described and one new combination is made in the lichen genus *Parmelia* from southern Africa. The new species are *Parmelia insipida* Brusse, *P. nimbicola* Brusse, *P. ralla* Brusse and *P. squamatica* Brusse. The new combination is *Parmelia leptoplaca* (Zahlbr.) Brusse. The affinities, chemistries and distributions of these species are discussed.

INTRODUCTION

The five species dealt with here, are rather unusual for the genus *Parmelia* in that they have crustose thalli with effigurate margins. The lower cortex is fused to the rock substrate, except at the lobe apices, where the free lower surface can be observed. True rhizines are not present. In addition, the apothecia are much smaller than is usual for *Parmelia*, and sometimes remain immersed in the central areoles. This variation does not appear to be significant for a similar case exists in the genus *Tephromela*, where the apothecia may be large (and resemble those of the large majority of *Parmeliae*) or much smaller and immersed in areoles. The internal structure of the apothecia of these new species is consistent with that of *Parmelia*, except for a somewhat thicker subhymenium in the central area of the apothecium.

The new species cannot be adequately accomodated in either of the effigurate-crustose genera, *Protoparmelia* Choisy or *Protoparmeliopsis* Choisy. *Protoparmelia*, typified by *P. badia* (Hoffm.) Choisy, seems to be quite distinct because of the well separated, capped paraphyses, elongated ascospores (with length more than twice the breadth, and a more strongly amyloid tholus (Hafellner, 1984). Here the pycnidiospores are acicular as in *Parmelia*. On the other hand *Protoparmeliopsis*, typified by *Protoparmeliopsis muralis* (Schreb.) Choisy, cannot be used for these lichens, because there the pycnidiospores are long and thread-like, commonly being over 20 μm long and perhaps more importantly, being only around 0.5 μm in diameter (Poelt, 1958). However, the ascus of *Protoparmeliopsis* is poricidal with extension (as with *Parmelia*) and the tholus reacts in a similar manner to that of *Parmelia* in Lugols iodine solution.

NEW SPECIES

PARMELIA INSIPIDA Brusse, *sp. nov.*

Thallus crustosus et effiguratus, saxicola, usque ad 4 cm diametro. *Lobi* elongati, 0.25–1.0 μm lati, 80–130 μm crassi. *Thallus superne* viridis, emaculatus, isidiis sorediisque nullis. *Cortex superior* 20 μm crassus. *Stratum gonidiale* 30–65 μm crassum, algis *Trebouxiis*, 6–20 μm diametris. *Medulla* alba, 25–65 μm crassa. *Cortex inferior* 18 μm crassus, ad apices loborum solum bene evolutus. *Rhizinae* non bene evolutae. *Apothecia* immersa vel leviter elevata, usque ad 0.7 mm diametris. *Hypothecium* 28–33 μm crassum. *Subhymenium* 10–60 μm crassum. *Hymenium* 50–65 μm altum, J+ caeruleum. *Asci* clavati, cum tholis J+ caeruleis (fig. 1). *Ascosporae* octonae, ovales, hyalinae, 6.5–10.5 x 5.0–7.5 μm. *Pycnidia* globosa, 80–110 x 50–90 μm. *Pycnidiosporae* bacillares, 6.0–11.5 x 0.8 μm. *Thallus* acidum usnicum et acidum evernicum continens.

TYPUS: Cape, 3124 (Hanover): Lootsberg Pass between Graaff-Reinet and Middelburg, Sneeuwberg, on siltstone kranz and boulders on NE slope, alt. 1 800 m, (–DD) *F. Brusse 4692*, 1986.01.30 (PRE, holo-; BM, LD, US, iso-), fig. 4.

Thallus crustose and effigurate, saxicolous, up to 4 cm across. *Lobes* elongate, 0.25–1.0 mm broad, 80–130 μm thick. *Upper surface* green, lacking maculae, isidia and soredia. *Upper cortex* 20 μm thick. *Algal layer* 30–65 μm thick, algae *Trebouxia*, 6–20 μm diam. *Medulla* white, 25–65 μm thick. *Lower cortex* 18 μm thick, well developed only near the lobe tips. *Rhizines* not well developed. *Apothecia* immersed or only slightly emergent, up to 0.7 mm across. *Hypothecium* 28–33 μm thick. *Subhymenium* 10–60 μm thick. *Hymenium* 50–65 μm high, J+ blue. *Asci* clavate, eight-spored, tholus J+ blue (fig. 1). *Ascospores* oval, hyaline, 6.5–10.5 x 5.0–7.5 μm. *Pycnidia* globose, 80–110 x 50–90 μm. *Pycnidiospores* rods, 6.0–11.5 x 0.8 μm. *Chemistry*: Usnic acid in the upper cortex and evernic acid in the medulla.

This species resembles the more common *Parmelia leptoplaca* (Zahlbr.) Brusse, with which it sometimes grows on the same rock. The latter species is a little larger and deeper yellow in colour, and can be separated from this new species by the presence of salazinic acid in the medulla.

Parmelia insipida is known from the eastern Cape Province, from the Sneeuwberg north of Graaff-Reinet to the south-western end of the Drakensberg north of Elliot. *Parmelia leptoplaca* is much more widespread and common, being present throughout the Great Karoo in a broad sense.

CAPE.—3127 (Lady Frere): 17 km N of Elliot, Barkleys Pass, on Clarens sandstone kranz on SW slope, alt. 2 050 m (–BB), *F. Brusse 4616*, 1986.01.27 (PRE).

PARMELIA NIMBICOLA Brusse, *sp. nov.*

Thallus crustosus et effiguratus, saxicola, usque ad 1.5 cm diametro. *Lobi* elongati, 0.2–0.6 mm lati, 100–115 μm crassi. *Thallus superne* cinereus, emaculatus, isidiis sorediisque nullis. *Cortex superior* 15–20 μm crassus. *Stratum gonidiale* 30–45 μm crassum, algis *Trebouxiis*, 4–17 mm diametris. *Medulla* alba, 50–60 μm crassa. *Cortex inferior* 6–10 μm crassus, ad apices loborum solum bene evolutus. *Thallus inferne* pallidus. *Rhizinae* non bene evolutae. *Apothecia* sessilia, usque ad 1 mm diametris. *Hypothecium* 25–45 μm crassum. *Subhymenium* 20–50 μm crassum. *Hymenium* 45–55 μm altum,

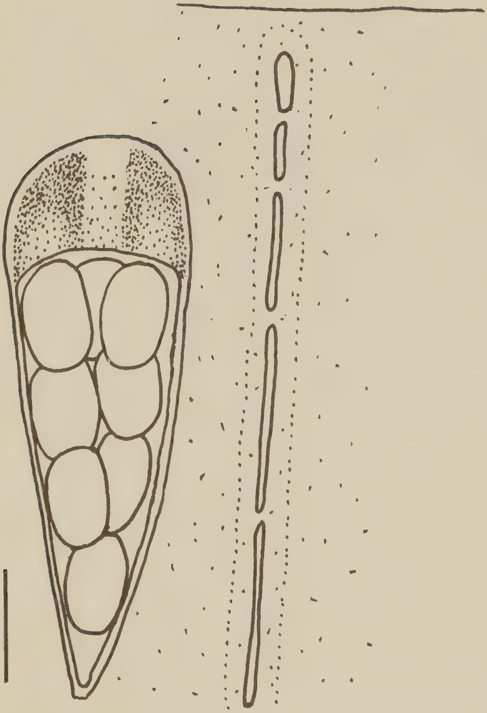


Fig. 1. *Parmelia insipida* Brusse, ascus and paraphyses. *F. Brusse 4692*, holotype. Bar = 10 µm.

J+ caeruleum. *Asci* clavati, cum tholis J+ caeruleis (fig. 2). *Ascosporae* octonae, ellipsoideae, 8.0–11.5 x 5.5–7.0 µm. *Pycnidia* ignota. *Thallus* atranorinum et acidum succinoprotocetraricum continens.

TYPUS: Cape, 3322 (Oudtshoorn): Robinsons Pass between Mossel Bay and Oudtshoorn, SW slopes of Ruitersberg, on Table Mountain sandstone outcrops, alt. 790 m (–CC), *F. Brusse 4807*, 1986.02.04 (PRE, holo-; BM, LD, iso-), fig. 5.

Thallus crustose and effigurate, saxicolous, up to 1.5 cm across. *Lobes* elongate, 0.2–0.6 mm broad, 100–115 µm thick. *Upper surface* grey, lacking maculae, isidia and soredia. *Upper cortex* 15–20 µm thick. *Algal layer* 30–45 mm thick, algae *Trebouxia*, 4–17 µm diam. *Medulla* white, 50–60 µm thick. *Lower cortex* 6–10 µm thick. *Lower surface* pale. *Rhizines* not well developed. *Apothecia* sessile, up to 1 mm across. *Hypothecium* 25–45 µm thick. *Subhymenium* 20–50 µm thick. *Hymenium* 45–55 µm high, J+ blue. *Asci* eight spored, clavate, tholus J+ blue (fig. 2). *Ascospores* ellipsoid, 8.0–11.5 x 5.5–7.0 µm. *Pycnidia* unknown. *Chemistry*: Atranorin in the upper cortex and succinoprotocetraric acid in the medulla.

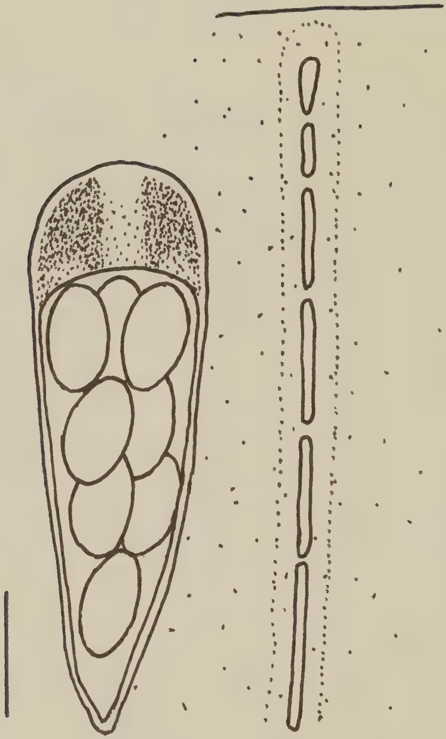


Fig. 2. *Parmelia nimbicola* Brusse, ascus and paraphyses. *F. Brusse 4807*, holotype. Bar = 10 µm.

This new species is the first crustose *Parmelia* with atranorin in the upper cortex. The recently described *P. astricta* (Brusse, 1984), *P. fausta, P. insignis* and *P. pudens* (Brusse, 1986), are also narrow lobed small species, but they are clearly foliose and not crustose. *P. nimbicola* was found on the western end of the Outeniqua mountains, north of Mossel Bay. This is an unusual habitat for a crustose *Parmelia* since this locality is very often shrouded in mist and the rainfall is relatively high. There are no close relatives of this species known at present.

P. nimbicola is presently known only from the type locality.

PARMELIA RALLA Brusse, *sp. nov.*

Thallus crustosus et effiguratus, interdum dispersus, saxicola, usque ad 3.5 cm diametro. *Lobi* elongati vel sublineares, 0.2–0.5 mm lati, 100–120 µm crassi. *Thallus superne* viridis, emaculatus, sorediis isidiisque nullis. *Cortex superior* 10–20 µm crassus. *Stratum gonidiale* 30–70 µm crassum, algis *Trebouxiis*, 5–18 µm diametris. *Medulla* alba, 15–50 µm crassa. *Cortex inferior* 9–13 µm crassus, ad apices loborum solum bene

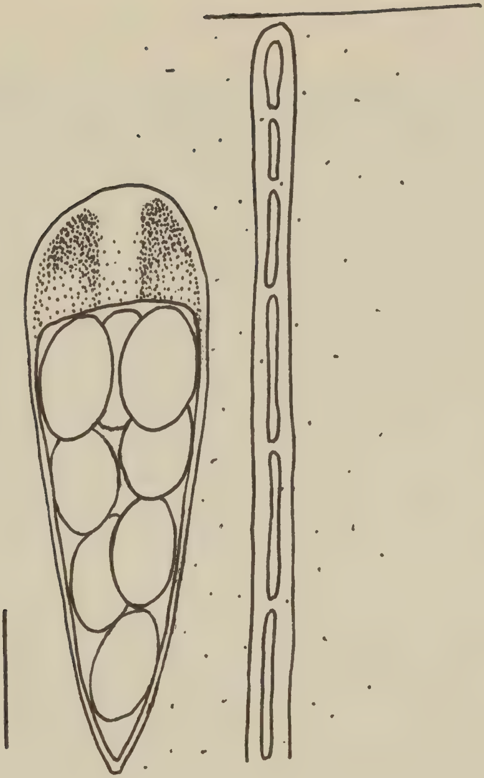


Fig. 3. *Parmelia ralla* Brusse, ascus and paraphyses. *F. Brusse 4935*, holotype, Bar = 10 µm.

evolutus. *Rhizinae* non bene evolutae. *Apothecia* sessilia, usque ad 0.7 mm diametris. *Hypothecium* 30–55 µm crassum. *Subhymenium* 25–40 µm crassum. *Hymenium* 45–55 µm altum, J+ caeruleum. *Asci* clavati, tholis J+ caeruleis (fig. 3). *Ascosporae* octonae, ellipsoideae, 8.0–10.5 x 5.0–7.0 µm. *Pycnidia* globosa, 100–150 x 85–120 µm. *Pycnidiosporae* bacillares, 7.5–13 x 1 µm. *Thallus* acidum usnicum et norlobaridonum continens.

TYPUS: Cape, 3321 (Ladismith): Swartberg range, Seven Weeks poort, 8,6 km NW of Amalienstein, on Table Mountain sandstone boulders on SW slope, alt. 670 m (–AD), *F. Brusse 4935*, 1986.02.10 (PRE, holo-; BM, COLO, LD, MEL, US, iso-), fig. 6.

Thallus crustose and effigurate, sometimes dispersed, saxicolous, up to 3.5 cm across. *Lobes* elongate to sublinear, 0.2–0.5 mm broad, 100–120 µm thick. *Upper surface* green, lacking maculae, isidia and soredia. *Upper cortex* 10–20 µm thick. *Algal layer* 30–70 µm thick, algae *Trebouxia*, 5–18 µm diam. *Medulla* white, 15–50 µm thick. *Lower cortex* 9–13 µm thick, well developed at lobe apex only. *Rhizines* not well developed. *Apothecia* sessile, up to 0.7 mm across. *Hypothecium* 30–55 μm thick. *Subhymenium* 25–40 μm thick. *Hymenium* 45–55 μm high, J+ blue. *Asci* clavate, eight-spored, tholus J+ blue (fig. 3). *Ascospores* ellipsoid, 8–10.5 x 5.0–7.0 μm. *Pycnidia* globose, 100–150 x 85–120 μm. *Pycnidiospores* rods, 7.5–13 x 1 μm. *Chemistry*: Usnic acid in the upper cortex and norlobaridone in the medulla.

This new species resembles other crustose *Xanthoparmeliae*, but has more elongated, sublinear lobes. The norlobaridone in the medulla readily distinguishes this new species from morphologically similar taxa. *P. ralla* has been found from Uniondale to Ladismith, on Table Mountain sandstone.

Cape.—3323 (Willowmore): 5 km S of Uniondale, Uniondale poort, on steep SW slope, on TMS outcrops, alt. 830 m (–CA), *F. Brusse 4768*, 1986.02.03 (PRE).

PARMELIA SQUAMATICA Brusse, *sp. nov.*

Thallus crustosus et effiguratus, saxicola, usque ad 5 cm diametro. *Lobi* elongati, 0.2–0.7 mm lati, 100–300 μm crassi. *Thallus superne* viridis, emaculatus, sorediis isidiisque nullis. *Cortex superior* 10–20 μm crassus. *Stratum gonidiale* 30–80 μm crassum. *Medulla* alba, 60–200 μm crassa. *Cortex inferior* 10–15 μm crassus, ad apices loborum solum bene evolutus. *Thallus inferne* pallidus. *Rhizinae* non bene evolutae. *Apothecia* non visa. *Pycnidia* circa 50 μm diametris, globosa. *Pycnidiosporae* bacillares, 7–11 x 1 μm. *Thallus* acidum usnicum et acidum squamaticum continens.

TYPUS: Cape, 3219 (Wuppertal): Summit of Pakhuis Pass, near Clanwilliam, on TMS boulders and outcrops on SW slope, alt. 900 m (–AA), *F. Brusse 772 8–2–1*, 1977.02.08 (J, holo-), fig. 7.

Thallus crustose and effigurate, saxicolous, up to 5 cm across. *Lobes* elongate, 0.2–0.7 mm broad, 100–300 μm thick. *Upper surface* green, lacking maculae, isidia and soredia. *Upper cortex* 10–20 μm thick. *Algal layer* 30–80 μm thick. *Medulla* white, strongly UV_{366} fluorescent (white), 60–200 μm thick. *Lower cortex* 10–15 μm thick, well developed at lobe tips only. *Lower surface* pale, without well developed rhizines. *Apothecia* not seen. *Pycnidia* around 50 μm diam., globose. *Pycnidiospores* rods, 7–11 x 1 μm. *Chemistry*: Usnic acid in the upper cortex and squamatic in the medulla.

This new species resembles other crustose *Xanthoparmeliae*, but can be distinguished from them most readily by the presence of squamatic acid in the medulla, which causes a strong white fluorescence in long wave ultraviolet light.

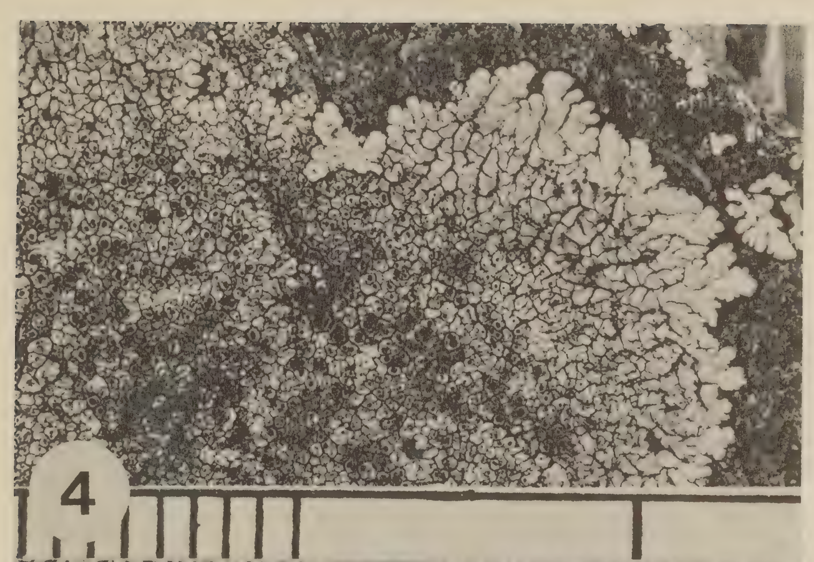
At present this species is known only from the type locality.

NEW COMBINATION

PARMELIA LEPTOPLACA (Zahlbr.) Brusse, *comb. nov.*

Basionym: *Lecanora leptoplaca* Zahlbruckner, A., *Ann. Crypt. Exot. 5*: 249, 1932.

TYPUS: Kapland, Laingsburg (grosse Karroo), Sandsteinfelsen, c. 700 m, J. Brunnthaler, 11.11.1909 (W 626!).



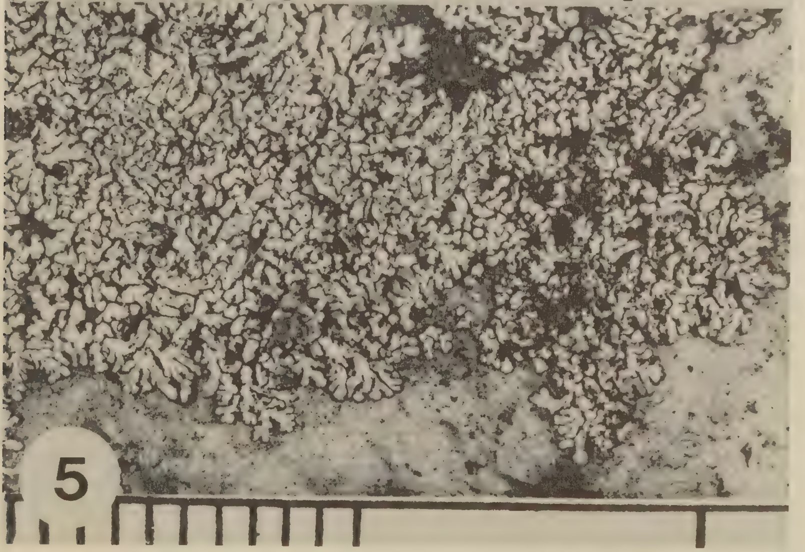
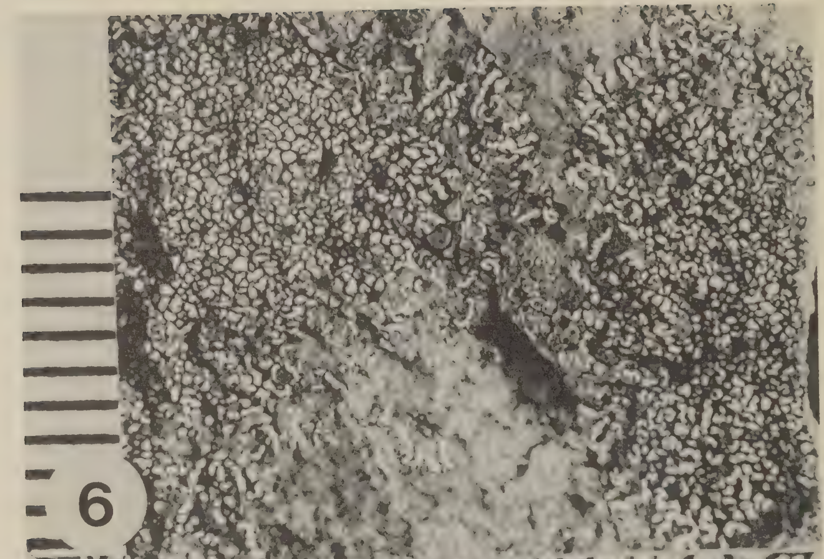


Fig. 4. *Parmelia insipida* Brusse, habit *F. Brusse 4692*, holotype. Scale in mm and cm.

Fig. 5. *Parmelia nimbicola* Brusse, habit. *F. Brusse 4807*, holotype. Scale in mm and cm.



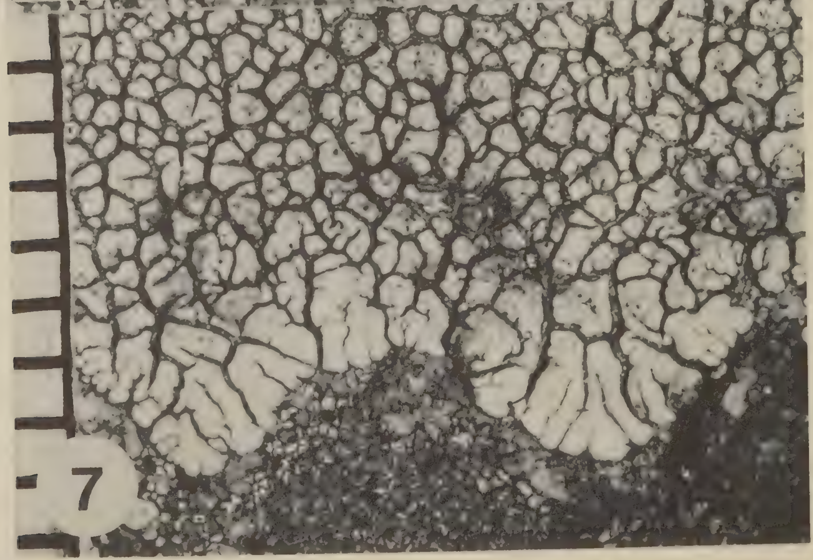


Fig. 6. *Parmelia ralla* Brusse, habit. *F. Brusse 4935*, holotype. Scale in mm and cm.

Fig. 7. *Parmelia squamatica* Brusse, habit. *F. Brusse 772 8–2–1*, holotype. Scale in mm.

ACKNOWLEDGEMENTS

The author is grateful to the South African Department of Agriculture and Water Supply for financial support. Thanks are also extended to Dr John A. Elix for reviewing this paper. The author is also thankful to Mrs A.J. Romanowski for the photography and to Mrs S.S. Brink and Mrs E. Bunton for the typing.

LITERATURE CITED

BRUSSE, F.A. 1984. New species and combinations in *Parmelia* (Lichenes) from southern Africa. *Bothalia* **15** (1 & 2): 315–321.

BRUSSE, F.A. 1986. Five new species of *Parmelia* (Lichenes, Parmeliaceae) from southern Africa. *Mycotaxon* in press.

HAFELLNER, J. 1984. Studien in Richtung einer natürlichen Gliederung der Sammelfamilien Lecanoraceae und Lecideaceae. *Beih. Nova Hedwigia* **79**: 241–371.

POELT, J. 1958. Die lobaten Arten der Flechtengattung *Lecanora* Ach. *sensu ampl.* in der Holarktis. *Mitt. bot. Staatss. München* **2**: 411–573.

MYCOTAXON

Vol. XXVII, pp. 247-253 October-December 1986

BERTIELLA (SACC.) SACC. & SYDOW A SYNONYM OF MASSARINA SACC.

Ove Eriksson
Institute of Ecological Botany,
University of Umeå, S-90187 Umeå, Sweden.

and

Jing-zhu Yue
Institute of Microbiology,
Academia Sinica, Beijing, PRC - China.

ABSTRACT

The generic type **Bertiella macrospora** (Sacc.) Sacc.& Sydow is a **Massarina** species, **M. macrospora** (Sacc.) O. Eriksson & J.-z. Yue. It is compared with some **Lophiostoma** spp. and **M. coccodes** (Karsten) O. Eriksson & J.-z. Yue.

INTRODUCTION

During our studies of Chinese pyrenomycetes, we examined material identified as **Bertia macrospora** Sacc. (Tai 1979: 89, Herb. HMAS) and found that all collections were **Bertia moriformis** (Tode: Fr.) De Not. var. **latispora** Corlett & Krug. However, Nannfeldt (1975: 291) reported that **B. macrospora**, type of the genus **Bertiella** (Sacc.) Sacc. & Sydow, is a bitunicate fungus. In order to clarify the true systematic position of this genus, we examined original material of **B. macrospora**. We found that Nannfeldt's opinion is correct, and that the species should be referred to **Massarina** Sacc.

MATERIALS AND METHODS

Methods used in this study are described in Eriksson & Yue (1985) and Yue & Eriksson (1985).

TYPE OF BERTIELLA (SACC.) SACC.

Massarina macrospora (Sacc.) O. Eriksson & J.-z. Yue, comb. nov. - Basionym: **Bertia macrospora** Sacc., Michelia 1: 452 (1878).

Fig.: 1.

Ascomata superficial on wood, but possibly originally covered by cortex, ± gregarious and sometimes confluent, subglobose with a flat base or more irregular in shape; surface often slightly striated along the grain, non-papillate, non-setose, black, carbonaceous. Ascomal wall ca. 60-70 µm thick, partly consisting of ± isodiametric cells with strongly melanized, dark brown walls in outer parts of ascomata, with thin-walled hyaline walls in inner parts, partly of less dark-coloured bands of elongated cells, somewhat resembling a cephelothecioid cell arrangement. Hamathecium of numerous, filiform, ca. 2 µm wide, branched paraphysoids. Asci numerous, cylindric-clavate, short-stalked, ca. 130-150 x 22 µm, bitunicate. Ectotunica thin; endotunica very thin in lower half of mature ascus, thicker

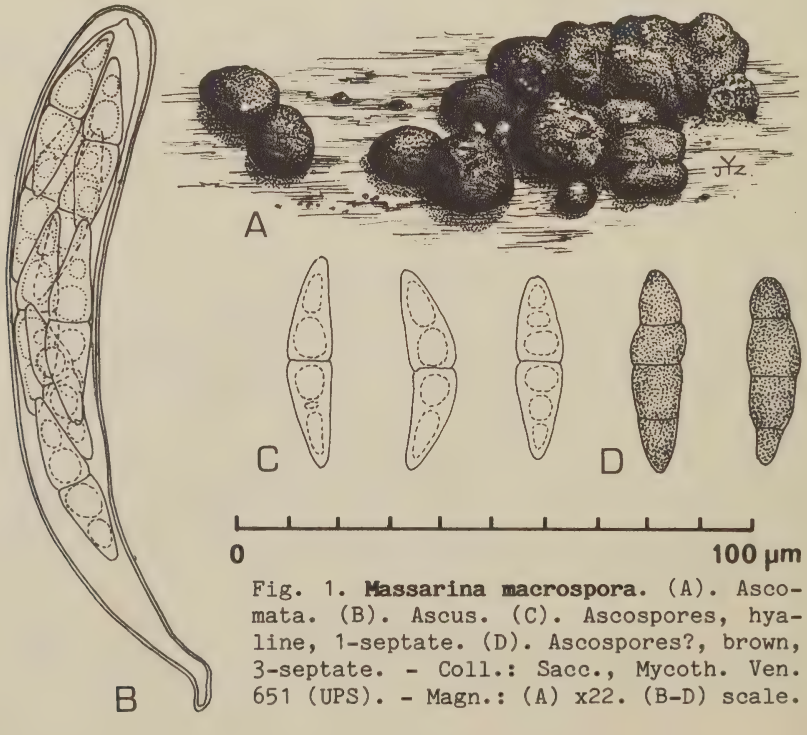


Fig. 1. **Massarina macrospora**. (A). Ascomata. (B). Ascus. (C). Ascospores, hyaline, 1-septate. (D). Ascospores?, brown, 3-septate. - Coll.: Sacc., Mycoth. Ven. 651 (UPS). - Magn.: (A) x22. (B-D) scale.

towards the apex and with a small ocular chamber, but no ring structures, its innermost parts staining dark with Chlorazol black. Ascospores ca. 37-43 x 8-9 µm, fusiform, inequilateral, 1-septate, hyaline, with 2-3 globules in each hemispore, smooth, without gelatinous sheath.

On wood of **Fagus sylvatica**, Italy, Treviso, Consiglio, P.A. Saccardo, Mycoth. Ven. 651 (UPS).

DISCUSSION

Bertia subg. **Bertiella** Sacc. (1882: 584) was raised to generic rank by Saccardo (1899: 19). The subgenus originally contained two species, **Bertia macrospora** Sacc. and **B. parasitica** Fabre. Clements & Shear (1931: 270) selected **B. macrospora** as type species of the genus **Bertiella** (Sacc.) Sacc. & Sydow. It should be mentioned that Kirschstein (1906: 51) used the name **Bertiella** for another genus, based

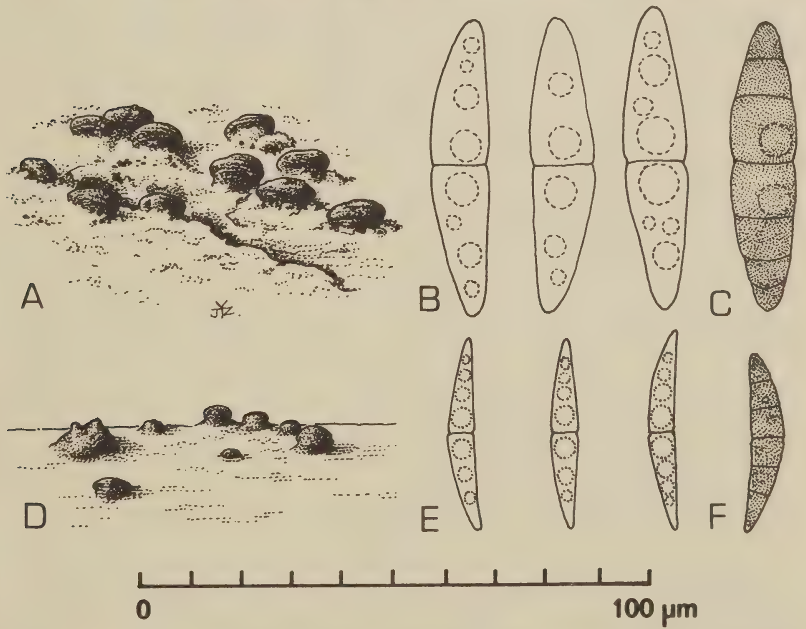


Fig. 2. (A-C). **Lophiostoma subcorticale**. (D, E). **L. semiliberum**. (F). **L. arundinis**. - (A, D). Ascomata. (B, C, E, F). Ascospores. - Coll.: (A-C). K. & L. Holm 3415a (UPS). (DE). O. Eriksson 2376d (UME 25621). (F). O. Eriksson 2490b (UPS). - Magn.: (A, D) x 22. (B, C, E, F) scale.

on **Bertiella polyspora** Kirschst. = **Kirschsteinia polyspora** (Kirschst.) H. Sydow (1906: 455), which was subsequently (Kirschstein 1912: 289) identified as **Fracchiaea heterogena** Sacc. This name is a synonym of **Nitschkia broomeiana** (Berk.) Nannf.

The type species of **Bertiella** (Sacc.) Sacc. & Sydow, **Bertia macrospora**, was described by Saccardo in 1878. We studied original material (see above) and found that this species belongs to **Massarina.** This genus is characterized by perithecioid ascomata which are often almost hyaline in basal parts and unevenly pigmented in upper parts (opaque near the pseudostiole). They are immersed in most species, e.g. the type **M. eburnea** (Tul. & C. Tul.) Sacc., but some species have erumpent ascomata. The centrum consists of paraphysoids and bitunicate asci. These are rather thin-walled and produce 1-5-septate, hyaline ascospores. In some species the spores lack a distinct perispore, in others they are completely enclosed in a gelatinous layer. In one species, a potential pathogen of man in the Tropics, which is currently known as **Leptosphaeria senegalensis** Segretain & al. (not validly published, ICBN Art. 37, which is why transfer to **Massarina** must await), the ascospores have a thick perispore with a characteristic appendage at the lower end (El-Ani & Gordon 1965: Figs. 1-4; Parguey-Leduc & al. 1982: Figs. 6-7). **Massarina macrospora** deviates from the majority of the species in the genus in their ascomata being almost superficial when mature.

We checked the reference literature for older names which might possibly be synonyms of **B. macrospora**, but none of the species in **Didymella** D. Sacc., **Massarina, Metasphaeria** Sacc., **Sphaeria,** or other relevant genera could possibly be conspecific with **B. macrospora**. However, **Massarina** is close to **Lophiostoma** Ces. & De Not. (incl. **Lophiotrema** Sacc.), the compressed ostiolar neck in this genus being the main distinguishing character from **Massarina,** As normal specimens with compressed ostiole are sometimes intermixed with others without such a neck, there was the possibility that the type collection of **B. macrospora** is only an atypical **Lophiostoma** species without compressed neck. Therefore, we also searched for possible synonyms in **Lophiosphaera** Trev., **Lophiotrema,** and **Lophiostoma.** We found that three species with older epithets may have similar hyaline, 1-septate ascospores.

1. **Lophiostoma subcorticale** Fuckel (Fig. 2 A-C) has spores with much the same shape as spores of **B. macrospora,** but they are normally about 50 % longer and wider (ca. 60 x 12 µm versus ca. 40 x 8 µm). Chesters & Bell (1970: 12)

have given spore measurements of 45-60 x 8-10 µm for **L. subcorticale**, but this interval probably includes measures for very young, immature spores. Fully ripe spores of **L. subcorticale** are multi-septate and brown. In one slide of **B. macrospora** we saw 3-septate, brown spores near ascomata, but we are not sure that they belong to that species. The ascomata of **L. subcorticale** are usually immersed in bark and the protruding necks distinctly compressed. Ascomata of **M. macrospora** are superficial on naked wood, but may originally have been covered by cortex. They have no necks.

2. **Lophiostoma angustilabrum** (Berk. & Br.) Cooke has shorter and narrower spores (cf. Chesters & Bell 1970: 8).

3. **L. semiliberum** (Desm.) Ces. & De Not.) (Fig. 2 D-F) is a graminicolous species with hyaline, 1-septate spores measuring about 34-38 x 5-6 µm. The ascomata are often more or less erumpent and the necks may be compressed, non-compressed or missing, but there always seems to be some ascomata with compressed neck in the same sample. **Lophiostoma arundinis** (Pers.: Fr.) Ces. & De Not., a similar species with 5-septate, brown spores, has been considered the mature stage of **L. semiliberum**.

Our conclusion is that there is no older epithet for **B. macrospora**, and that the correct name for the species is **Massarina macrospora** (Sacc.) O. Eriksson & J.-z. Yue.

In the dissecting microscope **M. macrospora** resembles **Leptosphaeria coccodes** Karsten, but the ascomal wall is thinner and of more homogeneous texture in that species, and the spores are distinctly swollen above the primary septum (see Eriksson 1967: 401). Munk (1956: 303) treated **L. coccodes** as the type of **Metasphaeria** Sacc. in the new family Massarinaceae. However, Clements & Shear had already cited "**M. sepincola** (Fr.) Sacc." as type for **Metasphaeria** in 1931 (this type was accepted by Holm in Farr & al. 1979: 1078). This is now called **Saccothecium sepincola** (Fr.) Fr., a species which is not related to **Metasphaeria** sensu Munk. There are, however, no important differences between the latter taxon and **Massarina**, and the correct name for Karsten´s fungus is **Massarina coccodes** (Karsten) O. Eriksson & J.-z. Yue comb. nov. (bas. **Leptosphaeria coccodes** Karsten, Fungi Fenn. exs., no. 963, 1870).

As mentioned above, the only difference between **Massarina** and **Lophiostoma** is the presence of compressed ostiolar necks in normal specimens of the latter genus. This is probably not a very important difference, but, for the time being, we suggest that the genera are kept separate, and that species with erumpent ascomata, lacking a compressed ostiolar neck, are placed in **Massarina**. However, future studies of the whole group may result in redefined generic limits. In any case, presence of compressed ostiolar neck is not a criterion of importance at the familial level, and the family Massarinaceae should be included in the Lophiostomataceae.

Lophiosphaera beckhausii (Nits.) Berl. & Vogl. may be a younger synonym for **Massarina macrospora**, but we have not seen any original material. The species is not treated by Chesters & Bell (1970).

ACKNOWLEDGEMENTS

We acknowledge with thanks the financial support for our work from Academia Sinica (Beijing) and the Swedish Natural Science Research Council (Stockholm). We are grateful to Prof. Dr. N. Lundquist, Dr. L. Holm and Dr. V. Shingler for reviewing the manuscript.

LITERATURE CITED

BOSE, S.K., 1961. Studies on Massarina Sacc. and related genera. - Phytopath. Z. 41: 151-213.

CHESTERS, C.G.C. & BELL, A.E., 1970. Studies in the Lophiostomataceae Sacc. - Mycol. Pap. 120: 1-55.

CLEMENTS, F.E. & SHEAR, S.L. 1931. The Genera of Fungi. - Hafner, New York.

EL-ANI, A.S. & GORDON, M.A. 1965. The ascospore sheath and taxonomy of Leptosphaeria senegalensis. - Mycologia 57: 275-278.

ERIKSSON, O. 1967. On graminicolous pyrenomycetes from Fennoscandia. - Ark. Bot. 6: 381-440.

- & YUE, J.-Z. 1985. Studies on Chinese ascomycetes. 1.Phaeosaccardinula dictyospora. - Mycotaxon 22: 269-280.

FARR, E.R., LEUSSINK, J.A. & STAFLEU, F.A. 1979. Index Nominum Genericorum. Vol. 2. - Bohn, Scheltema & Holkema, Utrecht, W. Junk, The Hague.

KIRSCHSTEIN, W. 1906. Neue märkische Ascomyceten. - Abhandl. Bot. Ver. Prov. Brandenburg 48: 39-61.

- , 1912. Sphaeriales. - Krypt.-Fl. Mark Brandenburg 7: 164-304.

MUNK, A. 1956. On Metasphaeria coccodes (Karst.) Sacc. and other fungi probably related to Massarina Sacc. (Massarinaceae n. fam.). - Friesia 5: 303-308.

NANNFELDT, J.A., 1975. Stray studies in the Coronophorales (Pyrenomycetes) 4-8. - Svensk Bot. Tidskr. 69: 289-335.

PARGUEY-LEDUC, A., JANEX-FAVRE, M.C., ANDRIEU, S., LACOSTE, L. & TRAORE, F. 1982. Les Périthèces et les asques du Leptosphaeria (?) senegalensis Segretain, Baylet, Darasse et Camain. II. Les asques et les ascospores. - Ann. Parasit. 57: 179-195.

SACCARDO, P.A. 1882. Sylloge Fungorum ... 2. - Padova.

- & SYDOW, P. 1899. Sylloge Fungorum ... 14. - Padova.

SYDOW, H. 1906. Referate und kritische Besprechungen - Ann. Mycol. 4: 453-470.

TAI, F.L. 1979. Sylloge Fungorum Sinicorum. - Sci. Press, Academia Sinica, Beijing.

YUE, J.-Z. & ERIKSSON, O. 1985. Studies on Chinese ascomycetes. 2. Sinodidymella verrucosa. - Mycotaxon 24: 293-300.

摘 要

属的模式 Bertiella macrospora (Sacc.) Sacc. 是 Massarina 的一个种—— M. macrospora (Sacc.) O. Eriksson & J.-z. Yue。曾把它与一些 Lophiostoma 的种和 M. coccodes (Karsten) O. Eriksson & J.-z. Yue 做了比较。

MYCOTAXON

Vol. XXVII, pp. 255-261 October-December 1986

A NEW CHLAMYDOMYCES SPECIES FROM ITALY

PERINI CLAUDIA

Dipartimento di Biologia Ambientale - Sezione Botanica
Università di Siena - Via P.A. Mattioli 4, 53100 Siena, Italy

Abstract

A new species of the monospecific genus Chlamydomyces, C. sympodialis, found on dead leaves of Quercus pubescens, is here described and illustrated.

An interesting Hyphomycete on dead leaves of Quercus pubescens was found in the Botanical Garden of Rome in April 1985. It produces 1-septate conidia and possesses an Aspergillus-like synanamorph.

The following description concerns observations on natural media; the attempt at isolation in pure culture (V-8 Agar) was successful.

Exsiccatum is available in the Mycological Herbarium of the Rome Botanical Garden (ROHB 131 C).

Chlamydomyces sympodialis sp. nov.

Coloniae effusae, floccosae, hyalinae, conidiis pallide inauratae--brunnae, mycelium conidiaque valde refracta. Mycelium superficiale. Conidiophora oriunda sicut ramificationes ex hyphis reptantibus vel aereis, macronematosa, mononematosa, flexuosa, geniculata, simplicia interdum rectis angulis ramosa, hyalina, septata, laevia, usque ad 325 µm longa, 2.5-5 µm lata, rami usque ad 185 µm longi. Cellulae conidiogenae monoblasticae vel polyblasticae, integratae, terminales vel intercalares, denticulatae, 80-130 µm longae; denticulus subconicus, in basi septatus, et in apice apertus, 2.3-5 µm longus, 1.5-2.7 µm in basi latus. Conidia solitaria, acropleurogena, 1-septata, napiformi-tubrinata, laevia, 26.5-39 x 18.5-25.5 µm; cellula superior subglobosa et in basi trunca, inaurata-brunnea, 14-23.5 µm; cellula inferior obconica fere, evadens in brevem apertam et truncam appendicem, pallida inaurata-brunnea. Status Aspergillus--similis: conidiophora mononematosa, simplicia, hyalina, septata, usque ad 56.5 µm longa; vesiculae subglobosae; phialides uniseriatae, ampulliformes, 6.5-10 x 3.5-6 µm. Phialoconidia catenulata, ellipsoidea vel subglobosa, laevia, 3.3-6 x 2.5-3.3 µm.

In foliis emortuis Q. pubescens, Rome, holotypus: ROHB 131 C.

Colonies effuse, floccose, hyaline, pale golden-brown after sporulation, mycelium and conidia refracting. Mycelium superficial. Conidiophores arising as branches from aerial or reptant vegetative hyphe, macronematous, mononematous, flexuous, geniculate, simple or sometimes branched at right-angles, septate, smooth, hyaline, up to 325 µm long, 2.5-5 µm wide, branches up to 185 µm long. Conidiogenous cells polyblastic or monoblastic, integrated, terminal or intercalary, denticulate, 80-130 µm long; denticles subconical, septate at the base and opened at the apex, 2.3-5 µm long and 1.5--2.7 µm wide at the base. Conidia solitary, acropleurogenous,1-septate turbinate-napiform, smooth, 26.5-39 x 18.5-25.5 µm; distal cell subglobose and truncate at the base, golden-brown, 14-23.5 µm long; proximal cell more or less obconical, terminating in a short, opened and truncate appendage, pale golden-brown. Aspergillus-like state: conidiophores consisting of a mononematous, simple, hyaline, septate stipe, up to 56.5 µm long and 3.3-5 µm wide, usually terminating in a subglobose vescicle, 11.5-15 x 10-12.5 µm. Phialides in a single series, ampulliform, 6.5-10 x 3.5-6 µm, produced numerous on the vescicle; phialides are sometimes produced on the unswollen apex of the stipe. Phialoconidia catenulate, subglobose to ellipsoid, hyaline, smooth, 3.3-6 x 2.5-3.3 µm.

The new species described is characterized by the presence of two kind of conidia. The small, 0-septate phialoconidia are produced in an Aspergillus-like stage, while the holoblastic ones are produced in a stage characterized by the presence of denticulate conidiophore and conidiogenous cells with a sympodial-like stucture.

Holoblastic conidiogenesis takes place with the swelling of the hyphal apex which, even at this early stage, greatly resembles the conidium. Below the slight constriction between the growing conidium and the conidiogenous cell apex develops a septum that, after the conidial secession, will identify with the basal septum of the denticle. Subsequently, a second septum develops in the submedian area of the conidium. On reaching maturity it detaches itself by means of a rhexolitic rupture in an especially weak point in the wall. Separation occurs in the lower part of the cell delimited by the basal septum of the denticle and by the submedian septum of the conidium. This cell, which presents cytoplasmatic continuity, can, at this stage, be considered a separating cell. After rupture, the basal part of the latter cell on the conidiogenous cell is identifiable as a subconical denticle septate at the base and open at the apex. The other portion, of a larger dimension, will become the proximal cell of the conidium that appears closed by a cytoplasmatic accumulation slightly above rupture point.

The conidia have been described as bicellular because, when

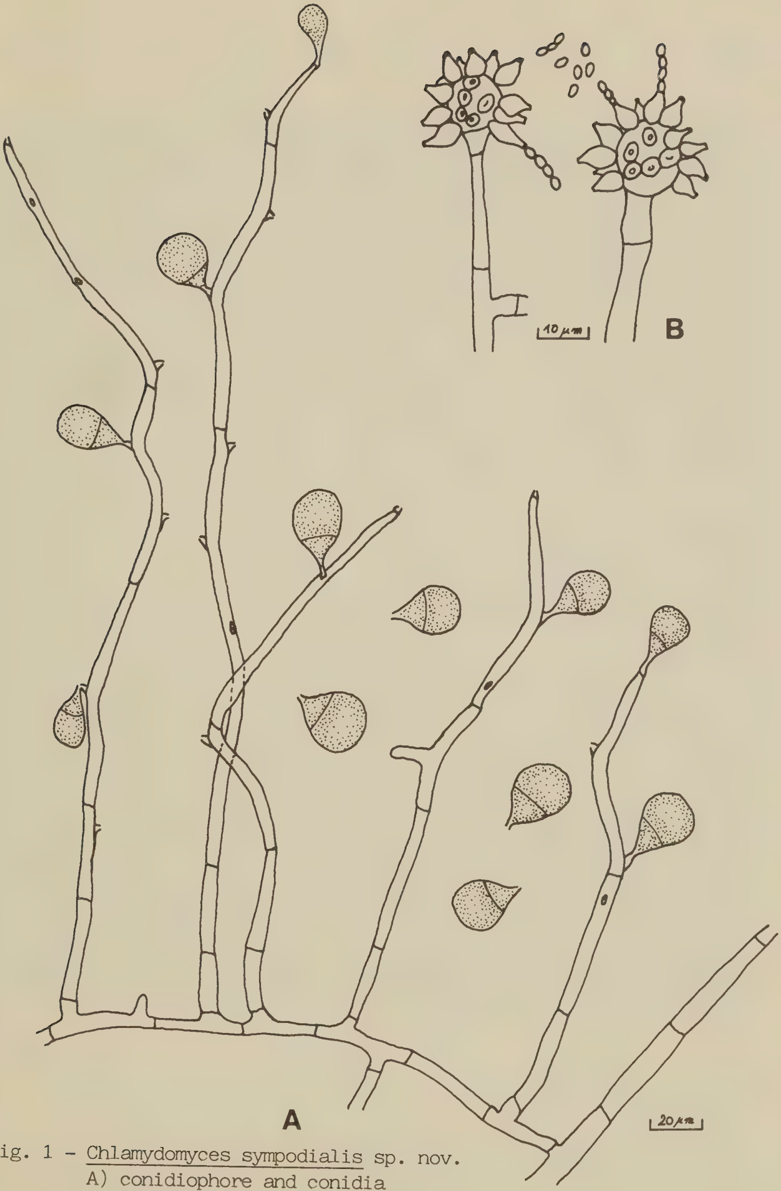

10 µm
B
A
20 µm

Fig. 1 - *Chlamydomyces sympodialis* sp. nov.
A) conidiophore and conidia
B) *Aspergillus*-like synanamorph

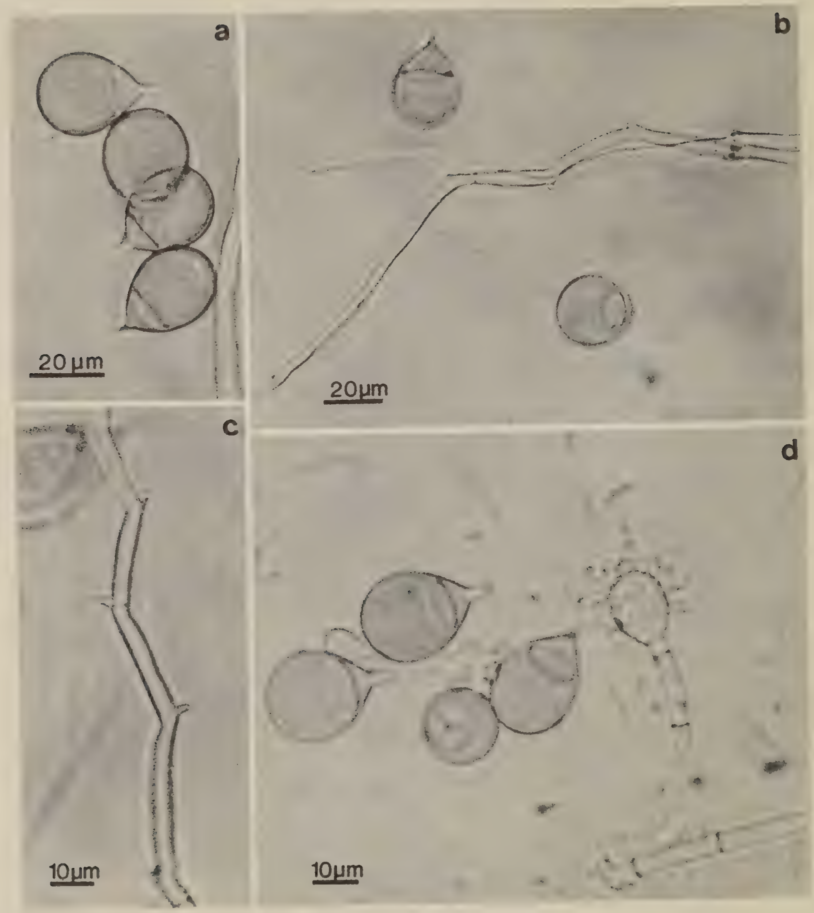

a
b
20µm
20µm
c
d
10µm
10µm

Fig. 2 - Chlamydomyces sympodialis sp. nov.
a) conidia
b) conidiophores
c) denticles
d) Aspergillus-like synanamorph

detached, they are formed by two cells, only the upper one of which is probably the real spora. Although the base of the proximal obconical cell is undelimited by a wall structure to divide it from the appendix,it conserves its cytoplasmatic content even after separation.

For this reason it is considered as belonging, in every respect, to the separated conidium. In fact, separation is considered the final stage of a conidiogenetic development and, for this reason, the mature conidium should therefore be described after, and not before, the actual separation.

The aspect of the conidiophore presumes a typically sympodial development.

In 1907 Bainier describes the new genus Chlamydomyces in the following way: "...Conidies bicellulaires à l'extrémité de supports à plusieurs étages de ramifications généralment opposées. Cellule supérieure sphérique ou ovale, tronquée à sa base, à paroi épaisse et de couleur accentuée. Cellule inférieure en tronc de cône renversé à paroi mince, lisse, incolore et translucide." No original material remains of the type species C. diffusus, that, in according to Bainier (1907), "...posséde un mycélium et des appareils fructiféres d' Acremoniella atra, donnant naissance à des spores de Mycogone cervina." Mason (1928) however, accepts the new genus Chlamydomyces for species that present "...large red or yellow two-celled macrospores, with maximum dimensions of about 40 x 28 µm" and that differ from Mycogone "... by the small, broadly cuneate (not subglobose) hyaline, smooth basal cell and by the fact that there is no constriction at the septum" and that, further, "...form an Aspergillus--like microconidial stage in culture." In this occasion the Author publishes the new combination C. palmarum rendering synonymous Trichobasis palmarum Cooke (1877), Uredo palmarum (Cooke) De Toni (1888), Mycogone rufa Petch, 1917 and proposing that C. diffusus, the type species of the genus, might also be considered among the synonyms. Finally, in 1976, Ellis nominates C. diffusus as a synonym of C. palmarum.

For a better understanding of the studied species the following authentic material has been examined:

Chlamydomyces palmarum (Cooke) Mason, MFC - 9083 - Host: Curcuma aromatica leaves; local.: Kuantzuling, Taiwan; Date: 7/11/1978 Ref.: Mats. Myc. Mem. 1:17, 1980

Mycogone rufa Petch, Herb. Hort. Reg. Bot. Kew. type - Host: plaintain fruit; Peradenija 4542; Date: 16/3/1915

Trichobasis palmarum Cooke, Herb. Hort. Reg. Bot. Kew, type - Host: cocopalm leaves; Demerara - Uredo 135 3084

The latter specimen was found to be quite old which rendered study very difficult. (Even when the species has been identified, it is extremely difficult to interpret particular structures).

The C. palmarum conidiophores are either simple or branched, branching being variable both in number and symmetry, often at right angles and sometimes composed of alternate placings. The conidia are bicellular; the upper cell is echinulate and thick-walled whereas the thin-walled, proximal obconical cell is sometimes pedunculate.

During holoblastic conidiogenesis two septa are subsequently formed: the first delimits the young, swollen conidium from the underlying cell; the second, being formed in the submedian position, divides the conidium in two cells. The underlying cell of the first septum formed appears to be divided by a stucture of difficult identification. According to Howell (1939) it seems a wall structure; but a careful microscopic study identicates that it is simply an area of a different cytoplasmatic density. Such a cell, considered conidiogenous, is lacerated during rhexolitic separation. Its apical portion sometimes remains as a peduncle at the base of the conidium; contrarily, the basal portion, of larger dimensions, remains on the conidiophore as a denticle, septate at the base and delimited apically by a cytoplasmic structure.

The presence of a conidiogenetic process and of a rhexolitic secession identical in all phases to those of C. palmarum and also of bicellular conidia and an Aspergillus-like stage, would seem to allow the inclusion of the species in Chlamydomyces. The species described differs, however, from the type species by its geniculated structure of the conidiophore and by the smooth apical cells of the conidia. The morphology of the conidiophore is less characteristic in C. palmarum and the conidia have a thick-walled, echinulate upper cell and a smooth, thin-walled basal cell. The form and dimensions of the Aspergillus-like stage also differ.

For the above mentioned reasons the new species C. sympodialis is proposed.

Acknowledgements

The Author whish to thank Prof. A. Rambelli and Dr. S. Onofri, Cattedra di Micologia, Dipartimento di Biologia Vegetale, Università degli Studi di Roma "La Sapienza", Rome, Italy, for their helpful suggestions and for kindly reviewing the manuscript.

REFERENCES

Bainier, M.G. 1907. Mycothéque de l'Ecole de Pharmacie de Paris. Bull. trim. Soc. Mycol. Fr., 23:235-241, pl. 26

Cooke, M.C. 1877. Cocoa-Palm fungi. Grevillea,35(5):101-103,pl.86

De Toni, J.B. 1888. Sylloge Ustilaginearum et Uredinearum" in Sylloge Fungorum, Saccardo P.A., Padova, Italy, 7:855

Ellis, M.B. 1976. More Dematiaceous Hyphomycetes. Commonw. Mycolog. Inst., Kew, England

Howell, A. 1939. Studies on Histoplasma capsulatum and similar form species. I. Morphology and development. Mycologia,31:191-216

Mason, E.W. 1928. Annotated account of fungi received at the imperial Boureau of Mycology. Myc. Pap., 2(1):37-39

MYCOTAXON

Vol. XXVII, pp. 263-269 October-December 1986

NOTES ON ENTOMOPHTHORALES (ZYGOMYCOTINA) COLLECTED BY T.PETCH: II. *ERYNIA ELLISIANA* SP. NOV., NON *ERYNIA FORFICULAE* (GIARD), COMB. NOV., PATHOGENS OF FORFICULIDAE (DERMAPTERA)

ISRAEL S. BEN-ZE'EV

Department of Plant Pathology and Microbiology,
Faculty of Agriculture, The Hebrew University
of Jerusalem, P.O.Box 12, Rehovot 76100, Israel

ABSTRACT

Empusa forficulae var. *major* Petch 1944 (nomen nudum) was reexamined and is redescribed here as an independent species, *Erynia ellisiana* Ben-Ze'ev, sp. nov., characterized by obovoid, uninucleate, bitunicate, subpapillate conidia averaging 23.8 x 15.2 µm, simple or rarely sparsely digitate conidiophores, and lack of pseudocystidia and rhizoids. *Entomophthora forficulae* Giard 1889 (=*Zoophthora forficulae* (Giard) Batko 1964) is transferred to *Erynia* as *E.forficulae* (Giard) Ben-Ze'ev, comb. nov. Both fungi are pathogens of Forficulidae (Dermaptera).

KEY WORDS: Entomophthorales; *Erynia ellisiana*; *E.forficulae*; Dermaptera; Forficulidae; *Forficula auricularia*.

Petch (1944) described a fungus pathogenic on earwigs, *Empusa forficulae* var. *major* Petch, as a variety of *Entomophthora forficulae* Giard (1889), which he transferred to *Empusa*, as *Empusa forficulae* (Giard) Petch. Since their original discovery, these two fungi were seldom mentioned in the literature, and then only for classification purposes, always quoting the original description (Guegen,1904 - quoted in Petch, 1944; Lakon, 1919; Hutchison, 1963; Batko, 1964, 1966; Waterhouse, 1975; Waterhouse and Brady, 1982). *E.forficulae* Giard was apparently reencountered only twice since its discovery: Rostrup (1893 - quoted in Petch,1944) recorded it in Denmark, and a photograph showing three European earwigs, *Forficula auricularia* L. killed by "*Entomophthora forficuli* Giard" in the United States, is shown in Steinhaus (1949) in his Fig. 102, without any further mention of this species in the text. The description of *E.forficulae* var. *major* in Waterhouse (1975) and again in Waterhouse and Brady (1982) added new data unmentioned by Petch (1944), on the existence and shapes of secondary conidia and resting spores. These additions were based on a personal communication from N. Wilding to G. Waterhouse (G. Waterhouse, pers. commun.)

The fungus described by Petch (1944) was collected by E.A. Ellis in England and resembled Giard's *E.forficulae* in having earwigs as hosts and in lacking rhizoids. According to Petch, this fungus difered from *E.forficulae* morphologically, in two ways: its conidiophores were simple whereas those of *E.forficulae* were described as sparingly branched, and its conidia were ca. 2.5 times wider, while their length was in the same range as those of *E.forficulae*. According with the common practice of classification at the level of species in the Entomophthorales, the two fungi should have been considered as different species on morphological grounds. However, Petch (1944) overemphasized the importance of the host, as he did in several other instances, and as a result failed to recognize new species, or mixed different species having a common host, in one description (Ben-Ze'ev and Kenneth, 1981; Ben-Ze'ev, 1982, 1986).

As there is no specimen of Giard's *E.forficulae* left for examination, one of Petch's specimens was reexamined in order to clarify the taxonomic position of *E.forficulae* var. *major* according to the modern classification of Entomophthorales, in which the old genus *Entomophthora* Fresenius had been split into five different genera, and some of its species had been transferred to *Conidiobolus* Brefeld.

MATERIALS AND METHODS

The specimen examined, from the T.Petch collection, was kindly lent by The Herbarium, Royal Botanical Gardens, Kew. It had no serial number and its annotation was: "*Empusa forficulae* (Giard) Petch var. *major* Petch n. comb., n. var., on earwigs, Old Lakenham, Norfolk.(Drawings made on date of collection, E.A. Ellis)". These drawings were redrawn, rearranged and provided with a scale, as Figs. 32-38 here.

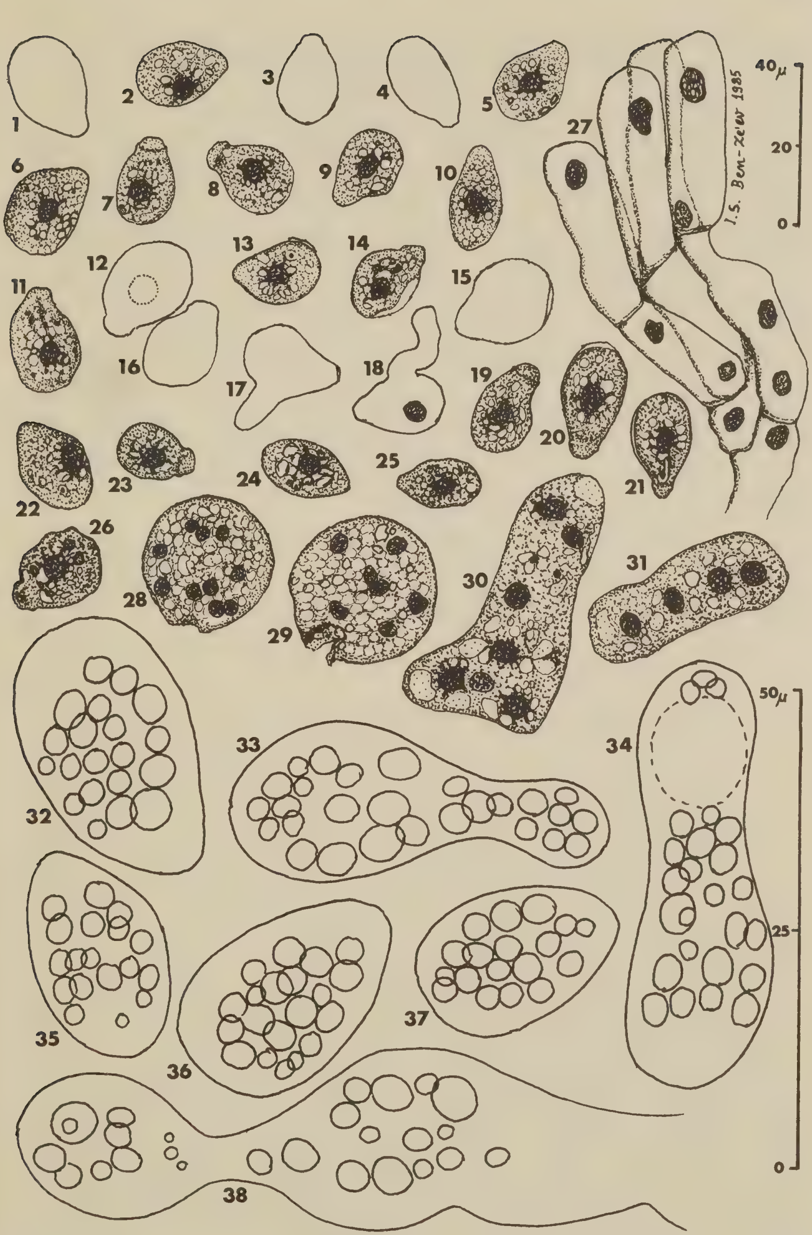
Small pieces of fungal material were scraped with fine dissecting needles from the outside and inside of the earwig's abdomen and were further dissected, in drops of acetocarmine or acetoorcein, under a dissecting microscope. The slides with the staining liquid and fungal material were gently heated to remove air bubbles and were sealed with coverslips. Measurements were taken with the aid of a calibrated eyepiece, so that each division = 0.79 µm at a magnification of 40 x 25 (objective x ocular). The limit of resolution was less than 0.5 division, < ± 0.4 µm. Figures 1 - 31 were drawn with the aid of a camera lucida.

RESULTS AND DISCUSSION

The specimen agreed, in macroscopic appearance, with the description of *Entomophthora forficulae* by Giard (1889), with Fig. 102 in Steinhaus (1949) and with Petch's (1944) description of *Empusa forficulae* var. *major*. The conidiophores emerged and filled the spaces between adjacent abdominal segments, and coalesced partially over some parts of the thorax. Some conidial shapes (Figs. 1-26) agreed with the description in Waterhouse (1975) and in Waterhouse and Brady (1982, no.65) and some

⟶

Figs. 1-38: *Erynia ellisiana* sp. nov.(≡*Empusa forficulae* var. *major* Petch): — 1-26, 32, 35-37: primary conidia; 30, 31, 33, 34: hyphal bodies; 27, 38: conidiophores, branched and unbranched, respectively; 28, 29: spherical bodies found in the type material — possibly immature resting spores, or structures unrelated to *E.ellisiana*; 1-31 drawn with the aid of a camera lucida at the scale shown at upper right; 32-38 reproduced from original drawing by E.A. Ellis at the scale shown at lower right.


40μ
I.S. Ben-Zeev 1985
50μ

with Ellis' drawings (compare Figs. 2,5,6,22, and 24 with 32,35,36 and 37). Conidiophores were in very poor condition, but appeared to be mostly unbranched as described by Petch (1944) and like Fig. 38 (redrawn from Ellis' drawings). One structure was found (Fig. 27) which closely resembled sparingly-branched conidiophores of some *Erynia* species, e.g. *E.suturalis* (Ben-Ze'ev, in preparation). It was difficult to determine whether this structure was a three-branched conidiophore to which another, simple one adhered, or a four-branched one. Mycelium and hyphal bodies (Figs. 30,31) were also in very poor condition. Many spherical, thin-walled bodies were present in the preparations (Figs. 28,29). These corresponded in size and yellow color with the resting spores of *E.forficulae* var. *major* described in Waterhouse (1975) and in Waterhouse and Brady (1982). However, several features seem to indicate that these spherical bodies might not belong to the fungus under consideration: a) the very thin walls and the numerous oily vacuoles filling these cells would indicate young prespores, yet, in no instance were these spherical bodies observed to be attached to hyphae or to hyphal bodies, and no signs have been observed on their walls to indicate any such attachment; b) the nuclei in the spherical bodies (Figs, 28,29) were substantially smaller than those in conidia and hyphal bodies (compare with other Figs.) Structures resembling mature entomophthoralean resting spores were not observed.

A comparison of conidial dimensions and other characters (Table 1) shows that the fungus described as *Entomophthora forficulae* var. *major* (Petch, 1944) is a species of *Erynia* Nowakowski emend. Humber & Ben-Ze'ev (1981), and deserves an independent status as a new species:

ERYNIA ELLISIANA Ben-Ze'ev, sp. nov. (Entomophthoraceae)
≡*Empusa forficulae* var. *major* Petch (nom. nud.),Trans. Br. mycol. Soc. 27:87 (1944).
NON Entomophthora forficulae Giard, Bull. Sci. Fr. & Belg. 20:211 (1889).

CONIDIA PRIMARIA obovoidea, hyalina, uninucleata, bitunicata, multivacuolata, plerumque subpapillata, raro epapillata aut papillata {secundum Lakoni (1919) systema}, 19.8-30.0 × 12.6-20.2 µm, med. 23.8 × 15.2 µm. CONIDIA SECUNDARIA globosa, primariis parviora, conidiophoris brevibus ex conidiis primariis portata. CONIDIORUM NUCLEI entomophthoroidei, elliptici, 4.0-6.3 × 3.2-5.5 µm, raro globosi, 4.0-6.3 µm diametro. CONIDIOPHORA PRIMARIA simplicia vel raro ramosa, determinata, ad 15 µm lata. SPORAE PERDURANTES, PSEUDOCYSTIDIA et RHIZOIDEA non observata. In Forficulidae (Dermaptera) in Britannia.

TYPUS: Exsiccati et lamina per microscopium, Erynia ellisiana *Ben-Ze'ev 1986 (≡*Empusa forficulae *var.* major *Petch) designata, Reg. Bot. Herb., Kew, Britannia.*

PRIMARY CONIDIA obovoid, hyaline, uninucleate, bitunicate, multivacuolate, mostly subpapillate, the rest epapillate or papillate {acc. to Lakon's (1919) classification}(Figs. 1-26 and 32,35-37) 19.8-30.0 × 12.6-20.2 µm ($\bar{x}$= 23.8 × 15.2 µm, s= 2.12 × 1.05 µm, n= 50), with a length/diameter ratio of 1.3-2.1 ($\bar{x}$= 1.58, s= 0.17, n= 50). The papillar proportional length (as % of total conidial length, epapillate conidia excluded) is 3.1-18.9% (most frequently 6-8%); papillar proportional width is 30-56.3% (m.f. 35-45%). SECONDARY CONIDIA were not observed in this study, but have been reported (Waterhouse, 1975) to be smaller than primary ones, globose, on short secondary conidiophores borne on primary

Table 1. A comparison of morphological characters of Entomophthorales recorded as attacking Forficulidae (Dermaptera).

SPECIES	PRIMARY CONIDIA Length × Diam. (min. - max.) $\bar{x}$ (μm)	CONIDIA Papillar Type	CONIDIOPHORES
HOST	Length / Diam. Ratio	Cytoplasm	
Entomophthora forficulae Giard, 1889	20-25 × 6-8 22 × 7	base hardly distinct from apex	sparingly branched
Forficula auricularia L.	3.1	completely without vacuoles	
E. forficulae (Rostrup, 1893, in Petch, 1944)	18-21 × 8-10 est. 19.5 × 9	?	?
?	?	?	
Empusa forficulae var. *major* Petch, 1944	20-30 × 15-18 ?	subpapillate or papillate (epapillate acc. to Ellis' drawings	unbranched
earwigs	?	multivacuolate acc. to Ellis' drawings	
Erynia ellisiana Ben-Ze'ev (≡*Empusa forficulae* var. *major* Petch) present study	19.8-28.4 × 12.6-20.6 23.8 × 15.2	mostly subpapillate some papillate and epapillate	mostly unbranched, rarely sparingly branched
earwigs	1.3 - 2.1 1.6	multivacuolate, uninucleate	

conidia. The lateral projections shown here on primary conidia (Figs. 17,18) could be such secondary conidiophores or ordinary germ-tubes. CONIDIAL NUCLEI are entomophthoroid, with granular heterochromatin which stained reddish-brown with acetoorcein and acetocarmine. The stain reaction was slower than in fresh material and apparently slower than in other preserved material, probably due to poor preservation. Nuclear shape was mostly ellipsoid, 4.0-6.3 × 3.2-5.5 μm, a smaller proportion were globose, 4.0-6.3 μm in diameter. PRIMARY CONIDIOPHORES (Figs. 27, 38) simple, rarely sparingly digitate, up to 15 μm wide. PSEUDOCYSTIDIA, RHIZOIDS and RESTING SPORES have not been observed in this study.
Pathogen of earwigs (Dermaptera: Forficulidae) in England.
TYPE: Specimen in T. Petch's collection annotated: *Eryni ellisiana* Ben-Ze'ev 1986 (≡*Empusa forficulae* var. *major* Petch) and microscope slides annotated similarly, deposited at The Herbarium, Royal Botanical Gardens, Kew, U.K.

This species is named in honour of Mr. E.A. Ellis, who collected it along with many other British entomogenous fungi described or studied by T. Petch.

When the genus *Zoophthora* Batko became a synonym of *Erynia* Nowakowski, most species of the former were transferred to the latter (Humber and Ben-Ze'ev, 1981; Ben-Ze'ev and Kenneth, 1982). *Entomophthora forficulae* was overlooked — the following new combination is therefore proposed:

ERYNIA FORFICULAE (Giard) Ben-Ze'ev, comb. nov.
basionym: *Entomophthora forficulae* Giard, Bull. Sci. Fr. & Belg. 20:211 (1889).
synonym: *Zoophthora forficulae* (Giard) Batko, Bull. Acad. Polon. Sci., Ser. Sci. Biol. cl II, 12:404 (1964).

The fungus recorded by Rostrup (1893, cited in Petch, 1944) on earwigs in Denmark (2nd in Table 1) appears to be a third, different species attacking earwigs.

For the time being, and until *E.forficulae* and *E.ellisiana* are reencountered and reexamined from fresh material and more subgeneric characters are described, it would be unsafe to decide to which subgenus of *Erynia* they belong, although their unbranched or sparingly branched conidiophores seem to indicate a possible affinity with the subgenus *Furia* (Batko) Li & Humber (1984).

ACKNOWLEDGMENTS

I thank the Curator of The Herbarium, Royal Botanical Gardens, Kew, U.K. for the loan of *E.forficulae* var. *major* material, and Ms Grace Waterhouse for valuable correspondence. I am grateful to Prof. Robert G. Kenneth (The Hebrew University of Jerusalem) for his constructive review of the manuscript, and to Prof. E.D. Kolman (Tel-Aviv University) for the Latin description.

REFERENCES

BATKO, A.(1964). Some new combinations in the fungus family Entomophthoraceae (Phycomycetes). *Bull.Acad.Polon.Sci.,Ser.Sci.Biol.cl II,* 12:*403-406*.

BATKO, A.(1966). On the subgenera of the fungus genus *Zoophthora* Batko 1964 (Entomophthoraceae). *Acta Mycol.* 2:*15-21*.

BEN-ZE'EV, I.(1982). *Erynia neopyralidarum* sp. nov. and *Conidiobolus apiculatus*, pathogens of pyralid moths, components of the misdescribed species, *Entomophthora pyralidarum* (Zygomycetes: Entomophthorales). *Mycotaxon* 16:*273-292*.

BEN-ZE'EV. I.(1986). Notes on Entomophthorales (Zygomycotina) collected by T. Petch: *Erynia anglica* comb. nov. and *Erynia coleopterorum*. *Mycotaxon* 25:*1-10*.

BEN-ZE'EV, I. and KENNETH, R.G.(1981). *Zoophthora radicans* and *Zoophthora petchi* sp. nov. (Zygomycetes: Entomophthorales), two species of the "*sphaerosperma* group" attacking leaf-hoppers and frog-hoppers (Homoptera). *Entomophaga* 26:*131-142*.

BEN-ZE'EV, I. and KENNETH, R.G.(1982). Features-criteria of taxonomic value in the Entomophthorales: II. A revision of the genus *Erynia* Nowakowski 1881 (=*Zoophthora* Batko 1964). *Mycotaxon* 14:*456-475*.

GIARD, A.(1889). Sur quelques types remarquables de champignons entomophytes. *Bull.Sci.Fr. & Belg.* 20:*197-224*.

HUMBER, R.A. and BEN-ZE'EV, I.(1981). *Erynia* (Zygomycetes: Entomophthorales): emendation, synonymy, and transfers. *Mycotaxon* 13:*506-516*.
HUTCHISON, J.A.(1963). The genus *Entomophthora* in the Western Hemisphere. *Trans.Kansas Acad.Sci*. 66:*237-254*.
LAKON, G.(1919). Die Insektenfeinde aus der Familie der Entomophthoreen. *Z.Angew.Entomol*. 5:*161-216*.
LI, Z. and HUMBER, R.A.(1984). *Erynia pieris* (Zygomycetes: Entomophthoraceae), a new pathogen of *Pieris rapae* (Lepidoptera: Pieridae): description, host range, and notes on *Erynia virescens*. *Can.J.Bot.* 62:*653-663*.
PETCH, T.(1944). Notes on entomogenous fungi. *Trans.Br.mycol.Soc.* 27:*81-93*.
STEINHAUS, E.A.(1949).'PRINCIPLES OF INSECT PATHOLOGY' Ist edition (ed. E.A. Steinhaus) *McGraw-Hill Book Comp.Inc.,New York, Toronto, London*
WATERHOUSE, G.M.(1975). Key to the species *Entomophthora* Fres. *Bull.Br.mycol.Soc.* 9:*15-41*.
WATERHOUSE, G.M. and BRADY, B.L.(1982). Key to the species of *Entomophthora sensu lato*. *Bull.Br.mycol.Soc.* 16:*113-143*.

NOTE ADDED IN PROOF

Since this article was accepted, it was brought to my attention that *Erynia forficulae* produces capilliconidia and belongs, therefore, to *Erynia* subgen. *Zoophthora* (Balazy, S.,1984 – Sbornik Dokl. simpoz. po teme KNTS-12U: Izucenie entomopatogennych microorganizmov, razrabota technologii i primenenija. Rytro-Poznan:141-157; and pers. commun.). The combination *Erynia (Zoophthora) forficulae*, used in that publication is not, however, effectively or validly published.

MYCOTAXON

Vol. XXVII, pp. 271-282 October-December 1986

CANOPARMELIA, PARAPARMELIA and RELICINOPSIS. THREE NEW GENERA IN THE PARMELIACEAE (LICHENIZED ASCOMYCOTINA)

JOHN A. ELIX, JEN JOHNSTON and DOUGLAS VERDON

Chemistry Department, The Faculties, Australian National University,
G.P.O. Box 4, Canberra, A.C.T. 2601, Australia

ABSTRACT: The genera *Canoparmelia* Elix and Hale gen. nov., *Paraparmelia* Elix and Johnston gen. nov. and *Relicinopsis* Elix and Verdon gen. nov. are here segregated from *Pseudoparmelia* s. str. The main differences between the genera lie in the chemical properties of the upper cortex and the medulla, the centres of distribution, the substrate and habitat requirements and the size of the conidia and spores.

Introduction

The lichen genus *Pseudoparmelia* was erected by Lynge in 1914 on the basis of a single collection from Brazil (Lynge 1914) and distinguished from *Parmelia* sens. lat. by the presence of "pseudocyphellae" on the lower surface. Santesson (1942) subsequently showed that the pseudocyphellae were artefacts caused by the rhizines being torn off the lower surfaces which revealed patches of the medulla.

More recently, Hale has accepted this typification of the genus (Hale 1974, 1976) (Type species: *Pseudoparmelia cyphellata* Lynge) and included in it all species previously accommodated in *Parmelia* subg. *Parmelia* section *Cyclocheila* (Hale and Kurokawa 1964) or *Parmelia* subgen. *Cyclocheila* (Krog & Swinscow 1979). The genus so defined could be recognized by the presence of simple rhizines and sublinear to irregularly widened, often apically subrotund, eciliate lobes. The apothecia were adnate to substipitate with imperforate discs and the upper cortex consisted of palisade plectenchyma with a pored epicortex.

Even so, it had become increasingly obvious that *Pseudoparmelia* so defined, was a heterogeneous assemblage of species (Hale 1974, 1976). As a result of further development and refinement of the generic concepts within the Parmeliaceae (Hale 1986) it is apparent that *Pseudoparmelia* sens. str. only includes a small group of species closely related to *P. cyphellata* Lynge: namely two other South American species, *P. hypomilta* (Fée) Hale and *P. chapadensis* (Lynge) Hale, plus as the more widely distributed lichen, *P. sphaerospora* (Nyl.) Hale. All contain the same medullary pigment (secalonic acid A) while the upper cortex contains only this pigment and atranorin (which is not accompanied by chloroatranorin). Further, the spores are small and nearly spherical (6 x 9 µm), the conidia are elongated bifusiform to filiform and the lower surface varies from a characteristic olivaceous brown to pale brown in colour, with sparse concolorous rhizines. This combination of characters clearly distinguishes *Pseudoparmelia* sens. str. from the remaining species previously included in this genus (Hale 1974, 1975, 1986). Very recently Hale (1986) has separated the (*Pseudo-*

parmelia) *caperata* group and transferred it to a new genus, *Flavoparmelia*.

During our revision of *Pseudoparmelia* sens. lat. in Australasia it was soon apparent that there were four segregate groups previously accommodated in *Pseudoparmelia* which are now excluded by the new circumscription of the genus. These were the *P. intertexta* group (*Relicinopsis*), the *P. scotophylla* group (*Paraparmelia*) and the *P. texana* groups (*Canoparmelia*, containing most of the species accommodated previously in this genus). These segregates differ from *Pseudoparmelia* sens. str. by a combination of morphological, distributional, ecological, cortical and chemical characters which have been summarized in Tables 1 and 2 and discussed below.

Morphology

The spores and conidia

While the overall morphology of the apothecia and spores are relatively uniform throughout the Parmeliaceae, the size of the spores is quite variable. For example, *Parmotrema* and *Flavoparmelia* (the Pseudoparmelia caperata group) consistently possess larger spores (greater than 14 µm long) than do other *Parmelia* sens. lat. segregates (less than 14 µm). By comparison *Pseudoparmelia* sens. str. has much smaller (4-7 x 6-9 µm), almost spherical spores as does *Relicinopsis* (ellipsoid, 3-5 x 5-8 µm). Analogous regularities in the size of spores are observed for *Canoparmelia* with smaller spores than *Flavoparmelia*, but larger than *Paraparmelia*, *Pseudoparmelia* and *Relicinopsis*; and *Paraparmelia*, which has spores smaller than *Canoparmelia*, but larger than those of *Pseudoparmelia* and *Relicinopsis*.

In several recent circumscriptions of parmelioid genera, considerable importance has been attributed to variations in the shape of the conidia (Krog 1982a). For example, *Punctelia* is the only parmelioid genus to consistently have unciform conidia while the related genus *Flavopunctelia* has bifusiform conidia (Krog 1982b, Hale 1984).

The conidia of *Pseudoparmelia* sens. str. are markedly elongated (12-20 µm) by comparison with those of allied genera (Table 1) and vary from elongated, weakly bifusiform to filiform in shape (Krog 1982a, b). At the other extreme, *Relicinopsis* and *Paraparmelia* are distinguished by their consistently short (5-7 µm) cylindrical and bifusiform conidia respectively. *Flavoparmelia* and *Canoparmelia* exhibit conidia of intermediate length (7-10 µm).

Thalline characters

Other major morphological distinctions between the segregates of *Pseudoparmelia* sens. lat. as well as the consistency of characters among the members of a particular segregate are apparent.

One such feature is the underside of the thallus. In *Pseudoparmelia* sens. str. the lower cortex always is brown to olivaceous or pale brown with concolorous rhizines which are always short, simple, and moderately dense to the lobe margins. In *Relicinopsis* the lower surface also is pale tan to brown in colour and rhizinate to the margins but the rhizines are dense, elongated and entangled, and in *R. intertexta* densely branched. The lower cortex of *Canoparmelia*, on the other hand, is black, with a narrow, naked, brown marginal zone, and simple concolorous rhizines which vary from sparse to dense. In *Paraparmelia* the colour of the lower surface varies from pale brown to jet black, and the rhizines are short, moderate to sparse, stout and occasionally tufted at the apices.

The occurrence of vegetative propagules amongst the segregates of

TABLE 1

SEGREGATES OF PSEUDOPARMELIA

GROUP	Pseudparmelia sens. str.	Flavoparmelia (caperata group)	Canoparmelia (texana group)	Paraparmelia (scotophylla group)	Relicinopsis (intertexta group)
Thallus Colour	Grey (-yellow)	Yellow -green	Grey	Grey	Yellow -green
Medulla (Colour)	Pigmented (yellow)	White (± lower medulla pigmented)	White	White (lower medulla rarely pigmented)	White.
Substrate	Corticolous & Saxicolous	Corticolous & Saxicolous	Corticolous & Saxicolous	Saxicolous	Corticolous
Habitat	Tropical forest & woodland	Temperate forests & dry woodland	Subtropical & tropical forest & woodland	Arid, subarid and temperate areas	Montane forest canopy and tropical forest
Distribution (major)	Central & south America & Africa (1 sp.)	Cosmopolitan	Pantropical	Australasia, South Africa	SE Asia, Indonesia, Australia, India
Spores µm	4-7 × 6-9	7-10 × 14-20	6-8 × 10-14	4-6 × 7-10	3-5 × 5-8
Conidia µm	bifusiform - filiform 12-20	bifusiform (rarely fusiform) 6-10	fusiform - bifusiform 7-10	bifusiform 5-7	fusiform - cylindrical 5-7
Lobes	short, narrow	rotund, broad	subrotund, ± medium	sublinear, narrow	linear-elongate, narrow
Lower surface	Brown to pale brown	Black	Black	Pale brown to black	Pale brown to tan
Vegetative propagules	Isidia 25%	Soredia, dactyls 50%	Soredia-pustules, isidia (40%) (25%)	Isidia, pustules-soredia 50% 10%	Isidia 50%
Rhizines	Moderate, simple	Moderate to sparse, simple	Moderate to dense, simple	Sparse to moderate, simple, stout, ± tufted	Dense, elongate, ± branched

Pseudoparmelia also is noteworthy. All genera include isidiate species, but sorediate and/or pustulate species are restricted to *Flavoparmelia*, *Canoparmelia*, and *Paraparmelia*. Fully 50% of the species of *Flavoparmelia* and 40% of *Canoparmelia* exhibit such propagules, but they are completely unknown in *Pseudoparmelia* sens. str. and *Relicinopsis*.

The lobe configuration is quite distinctive in two of the segregate groups. In *Relicinopsis* the lobes are typically sublinear-elongate and dichotomously branched, with the crowded or intricate lobe configuration forming a thallus with overall gross morphology similar to that of many species of *Relicina*. However, species of the latter genus are readily distinguished by the presence of the highly characteristic bulbate cilia and bifusiform conidia, whereas species of *Relicinopsis* are eciliate and have cylindrical to weakly fusiform conidia.

Although the lobe configuration is more variable in *Canoparmelia*, most species have relatively broad (3-5 mm wide), irregular lobes with rotund or subrotund apices. In *Paraparmelia* most species have relatively narrow (1-2 mm wide), sublinear to irregular lobes with subrotund apices. Small foliose or subcrustose thalline growth forms also are quite common in this genus.

Distribution

All three new genera have well defined centres of distribution. *Canoparmelia* has its highest number of species in the Americas and Africa, with some of the more widespread species, including *C. texana*, *C. caroliniana*, *C. carneopruinata*, *C. crozalsiana* and *C. salacinifera*, being essentially pantropical. *Relicinopsis*, on the other hand, is restricted to south-east Asia, the Indonesian archipeligo, Australia and the Indian subcontinent with one report from Ivory Coast in tropical Africa. *Paraparmelia* has two major centres of distribution both in the Southern Hemisphere, (i.e. South Africa and Australasia) and is rare outside these regions.

Ecology and Habitat

Although each of the genera exhibit some variability in their ecological requirements, overall habitat differences are very obvious.

Paraparmelia is confined to saxicolous substrates in the dry savannah woodland, subarid and arid areas of South Africa and Australasia. In marked contrast, *Relicinopsis* is always corticolous and restricted to the canopy and branches in tropical and montane rainforests. Most species of *Canoparmelia* also are corticolous, but some species, such as *C. caribaea* are primarily saxicolous. *Canoparmelia* species predominate in moist tropical and subtropical forests and woodland, and in this respect resemble *Pseudoparmelia* sens. str.

Chemistry

Cortical Chemistry

Despite the fact that Krog (1982 a,b) maintained that cortical chemistry is generally unimportant above species level in the Parmeliaceae, we beg to differ. For instance, Esslinger (1977, 1978) found that the distinctive cortical chemical reactions in the brown Parmeliae were an excellent means for differentiating *Melanelia*, *Allantoparmelia* and *Neofuscelia*. Indeed, Hale (1984) recently reinterpreted the generic characters in the case of *Punctelia* (cortical atranorin) and *Flavopunctelia* (usnic acid) and concluded that the cortical chemical differences in this case were mirrored by a number of significant morphological (conidial) and biogeographical differences. It is important to re-

TABLE 2

CHEMISTRY OF SEGREGATES OF PSEUDOPARMELIA

GROUP	*Pseudoparmelia* sensu stricto	*Flavoparmelia* (caperata group)	*Canoparmelia* (texana group)	*Paraparmelia* (scotophylla group)	*Relicinopsis* (intertexta group)
Chemistry (Medullary)					
Secalonic acids	present	uncommon	absent	absent	absent
Orcinol depsides	absent	absent	common	common	uncommon
β-Orcinol depsides	absent	uncommon	absent	absent	uncommon
Orcinol depsidones	absent	absent	absent	frequent	absent
β-Orcinol depsidones	common	common	common	common	common
Fatty acids	absent	common	uncommon	uncommon	common
Scabrosins	absent	absent	absent	uncommon	absent
Chemistry (Cortical)					
Secalonic acids	present	absent	absent	absent	absent
Atranorin	present	uncommon	present	present	uncommon
Chloroatranorin	absent	uncommon	present	uncommon	absent
Usnic acid	absent	present	uncommon	uncommon	present

iterate that no experimental or genetic proof has been introduced to deny the potential value of cortical chemistry as a discriminator. As Hale (1984) pointed out, a number of other lichen genera also are based partly on highly correlated cortical chemistry e.g. *Bulbothrix* Hale (atranorin) and *Relicina* (Hale & Kurokawa) Hale (usnic acid); *Bryoria* Brodo & Hawksw. (brown pigments) and *Alectoria* Ach. (usnic acid).

Cortical chemistry is particularly useful for distinguishing the segregates of *Pseudoparmelia* sens. lat. and is thus consistent with Hale's belief that the nature and morphology of the cortex constitute important taxonomic characters at the generic level (Hale 1981, 1984).

The upper cortex of all species of *Paraparmelia* contain atranorin rarely in conjunction with chloroatranorin (by h.p.l.c.). Only in *P. capnoides*, *P. fumigata*, *P. interposita* and *P. schistacea* are small amounts of usnic acid reported to occur (Kurokawa 1985) with atranorin, giving these grey species a slight yellowish tinge on the apical lobes. In *Relicinopsis* and *Flavoparmelia* the main cortical substance is usnic acid (occasionally with small amounts of atranorin) giving these species a distinct yellow or yellow-green colour.

The species of *Canoparmelia* invariably contain substantial quantities of both atranorin and chloroatranorin in the cortex while *Pseudoparmelia* sens. str. contains small quantities of atranorin together with the yellow medullary pigments, secalonic acid A and derivatives. The latter pigments give the upper surface of *Pseudoparmelia* sens. str. a dull yellowish cast. Several species of *Canoparmelia* (*C. ecaperata*, *C. zambiensis*) consistently contain sufficient quantities of usnic acid together with the major cortical substances, atranorin and chloroatranorin to colour the thallus yellow.

Medullary Chemistry

The main classes of medullary substances encountered in the species of *Pseudoparmelia* sens. str., *Canoparmelia*, *Paraparmelia* and *Relicinopsis* are detailed in Table 2. Although there is a significant overlap in medullary chemistry of the segregates, definite trends can be observed.

In *Paraparmelia* the β-orcinol depsidones (salazinic acid, hypostictic acid etc.) are predominant, whilst the orcinol depsidones (e.g. norlobaridone) and orcinol depsides (e.g. lecanoric acid) are less common.

In *Canoparmelia* the orcinol depsides divaricatic acid and lecanoric acid are particularly common, and the β-orcinol depsidones (stictic acid, salazinic acid, norstictic acid) occur frequently. Broad variations in medullary chemistry from biosynthetically primitive depsides, such as lecanoric acid, to more advanced depsidones has been reported previously in the Parmeliaceae. Such well-established and distant genera as *Parmotrema* and *Xanthoparmelia* exhibited parallel variations in medullary chemistry so the range of metabolites recorded for *Canoparmelia* and *Paraparmelia* are not inconsistent with these generic concepts. The β-orcinol depsidones also are most common in both *Pseudoparmelia* sens. str. and *Relicinopsis*, but barbatic acid (a β-orcinol depside) also is found in the latter. No orcinol depsides or depsidones have been observed in these genera, although a number of unknowns recorded for *Pseudoparmelia* sens. str. are not yet identified.

Paraparmelia and *Xanthoparmelia* (Vainio) Hale

In Australia and South Africa, species of both *Paraparmelia* and *Xanthoparmelia* (Vainio) Hale are well developed on rocks in subarid areas, and exhibit striking morphological parallels. Hale (Hale 1976) has interpreted these morphological similarities as representing an example of convergent evolution of the genera in these stressed environments. Even though there are parallels in overall morphology, ecological requirements and substrate preferences, we consider that the differences between the taxa warrant their segregation at the generic level.

Paraparmelia and *Xanthoparmelia* are clearly distinguished by cortical chemistry (atranorin ± chloroatranorin in *Paraparmelia*; usnic acid in *Xanthoparmelia*) although a small minority of species of *Paraparmelia* are known to develop pale yellow apical lobes due to the presence of traces of usnic acid. Even so, atranorin is the preponderant cortical metabolite in this genus and the upper surface of the lobes have a typical mineral-grey colour. Usnic acid is preponderant in the characteristic, yellow green upper cortex of the *Xanthoparmeliae*, but minor traces of atranorin may be detected occasionally. The significance of cortical chemistry has been discussed previously. The medullary-chemical profiles of these two genera also show significant differences - thus the β-orcinol depsides occur relatively frequently in *Xanthoparmelia* (*ca*. 10% of species in Australasia) but are unknown in *Paraparmelia*.

These two genera exhibit clear differences in world distribution. While *Paraparmelia* is confined largely to the Southern Hemisphere (South Africa, Australasia), *Xanthoparmelia* is widely distributed in both hemispheres with centres of speciation in North America (*ca*. 25% species) as well as Australia and South Africa. *Paraparmelia* and *Xanthoparmelia* also show some significant variations in substrate preference and thallus morphology. Although both genera are primarily saxicolous, many *Xanthoparmeliae* (20% of the 117 species in Australia) are obligately terricolous and commonly exhibit revolute or convolute lobes. *Paraparmelia* has not been observed to be terricolous, and is not known to exhibit a revolute- or convolute-lobed growth form.

Discussion

The main morphological, chemical, ecological and distributional traits of the species in *Pseudoparmelia* sens. str., *Relicinopsis* and *Paraparmelia* as well as the related segregates are outlined in Tables 1 and 2. They indicate that these segregates differ in a number of taxonomically important characters including spore size, conidial size and morphology, habitat preferences, cortical chemistry, centres of distribution, nature of vegetative propagules as well as several minor characters. Since relative uniformity can be demonstrated within each of the segregate groups, it provides substantial support for the proposed generic splits.

Canoparmelia Elix & Hale gen. nov.

Thallus foliaceus, pagina superior cinerea, pagina inferior nigra, rhizinas simplices instructa. Apothecia laminalia vel submarginali, discis integris, sporis octonis, ellipsoideis, 10-14x6-8 µm. Pycnidia laminalia vel raro marginalia, conidiis bifusiformibus vel fusiformibus vel cylindricis 7-10 µm longis et cortex superior atranorinum et chloroatranorinum continens.

Typus generis: *Canoparmelia texana* (Taylor) Elix & Hale.

Thallus foliose, lobes subrotund at the apices, (0.5)-3.0-5.0 (-8.0) mm broad, eciliate. Upper surface uniformly grey, with a perforate polysaccharide covering. Medulla white. Underside black, rhizinate, rhizines simple; with a narrow, paler, erhizinate zone at the

margins. Apothecia laminal or submarginal, disc entire, spores ellipsoid, simple, 8 per ascus, 10-14x6-8 µm. Pycnidia laminal or rarely marginal, conidia bifusiform more rarely cylindrical or weakly fusiform. The cortex containing atranorin and chloroatranorin ± usnic acid.
This new genus is considered to include the following species:

Canoparmelia adspersa (Vain.) Elix & Hale, comb. nov.
Basionym: *Parmelia adspersa* Vain., Hedwigia, **46**, 168. 1907.

Canoparmelia amazonica (Nyl.) Elix & Hale, comb. nov.
Basionym: *Parmelia amazonica* Nyl., Flora, Jena **68**, 611. 1885.

Canoparmelia aptata (Krempelh.) Elix & Hale, comb. nov.
Basionym: *Parmelia aptata* Krempelh., in Nylander, Fora, Jena **52**, 291. 1869.

Canoparmelia caribaea (Hale) Elix & Hale,, comb. nov.
Basionym: *Parmelia caribaea* Hale in Hale & Kurokawa, Contrib. U.S. Nat. Herb., **36**, 152. 1964.

Canoparmelia carneopruinata (Zahlbr.) Elix & Hale,, comb. nov.
Basionym: *Parmelia carneopruinata* Zahlbr., Sitzungs. kaiser. Akad. Wissen., Math.-Natur. Klasse, **1**, 419. 1902.

Canoparmelia caroliniana (Nyl.) Elix & Hale, comb. nov.
Basionym: *Parmelia caroliniana* Nyl., Flora, Jena **68**, 614. 1885.

Canoparmelia cinerascens (Lynge) Elix & Hale, comb. nov.
Basionym: *Parmelia cinerascens* Lynge, Arkiv Bot., **30B**, 104. 1914.

Canoparmelia concrescens (Vain.) Elix & Hale, comb. nov.
Basionym: *Parmelia concrescens* Vain. in F. Welwitsch, Cat. African Plants Collected by F. Welwitsch in 1853-61, **2**, 400. 1901.

Canoparmelia corrugativa (Kurok. & Filson) Elix & Hale, comb. nov.
Basionym: *Parmelia corrugativa* Kurok. & Filson, Bull. Natn. Sci. Mus., Tokyo, B, **1**, 38. 1975.

Canoparmelia crozalsiana (Bouly de Lesd.) Elix & Hale, comb. nov.
Basionym: *Parmelia crozalsiana* Bouly de Lesd. ex J. Harmand, Lichens de France, **4**, 555. 1910.

Canoparmelia cryptochlorophaea (Hale) Elix & Hale, comb. nov.
Basionym: *Parmelia cryptochlorophaea* Hale, Bryologist, **62**, 18. 1959.

Canoparmelia ecaperata (Müll. Arg.) Elix & Hale, comb. nov.
Basionym: *Parmelia ecaperata* Müll. Arg., Flora, Jena **74**, 378. 1891.

Canoparmelia epileuca (Hale) Elix & Hale, comb. nov.
Basionym: *Parmelia epileuca* Hale, Bryologist, **75**, 343. 1972.

Canoparmelia eruptens (Kurok.) Elix & Hale, comb. nov.
Basionym: *Parmelia eruptens* Kurok., in Hale & Kurokawa, Contrib. U.S. Nat. Herb., **36**, 153. 1964.

Canoparmelia inhaminensis (Dodge) Elix & Hale, comb. nov.
Basionym: *Parmelia inhaminensis* Dodge, Ann. Missouri Bot. Gard., **46**, 130. 1959.

Canoparmelia inornata (Hale) Elix & Hale, comb. nov.
Basionym: *Parmelia inornata* Hale, Phytologia, **22**, 32. 1971.

Canoparmelia martinicana (Nyl.) Elix & Hale, comb. nov.
Basionym: *Parmelia martinicana* Nyl., Flora, Jena **68**, 609. 1885.

Canoparmelia nairobiensis (Stein. & Zahlbr.) Elix & Hale, comb. nov.
Basionym: *Parmelia nairobiensis* ("neirobiensis") Stein. & Zahlbr. in Zahlbr., Bot. Jahrb. Syst., **60**, 517. 1926.

Canoparmelia norsticticata (Stevens) Elix & Hale, comb. nov.
Basionym: *Parmelia norsticticata* Stevens in Elix & Stevens, Aust. J. Bot., **27**, 881. 1979.

Canoparmelia raunkiaeri (Vain.) Elix & Hale, comb. nov.
Basionym: *Parmelia raunkiaeri* Vain., Ann. Acad. Scien. Fennicae, **6A**, 19. 1915.

Canoparmelia salacinifera (Hale) Elix & Hale, comb. nov.
Basionym: *Parmelia salacinifera* Hale in Hale and Kurokawa, Contrib. U.S. Nat. Herb., **36**, 157. 1964.

Canoparmelia schelpei (Hale) Elix & Hale, comb. nov.
Basionym: *Parmelia schelpei* Hale, Bryologist, **75**, 344. 1972.

Canoparmelia scrobicularis (Krempelh.) Elix & Hale, comb. nov.
Basionym: *Parmelia scrobicularis* Krempelh., Vid. Medd. Natur. For. Kjöbenhaven, **25**, 10. 1873.

Canoparmelia somaliensis (Müll. Arg.) Elix & Hale, comb. nov.
Basionym: *Parmelia somaliensis* Mull. Arg., Flora, Jena **68**, 501. 1885.

Canoparmelia subtiliacea (Nyl.) Elix & Hale, comb. nov.
Basionym: *Parmelia subtiliacea* Nyl., Flora, Jena **68**, 614. 1885.

Canoparmelia texana (Tuck.) Elix & Hale, comb. nov.
Basionym: *Parmelia texana* Tuck., Amer. J. Sci. Arts, ser. 2, **25**, 424. 1858.

Canoparmelia zambiensis (Hale) Elix & Hale, comb. nov.
Basionym: *Parmelia zambiensis* Hale, Bryologist, **75**, 346. 1972.

Canoparmelia zimbabwensis (Hale) Elix & Hale, comb. nov.
Basionym: *Parmelia zimbabwensis* Hale, Bryologist, **75**, 346. 1972.

Paraparmelia Elix & Johnston, gen. nov.

Thallus foliaceus, saxicola, adnatus vel laxe adnatus, lobis subirregularibus, marginibus eciliatis, paginae superiore epicorticato cinerea, atranorinum continens, subtus pallide brunneus vel niger, modice vel sparse rhizinosus, rhizinis simplicibus. Apothecia adnata, imperforata, sporis octonis, ellipsoideis, 4-6 x 7-10 µm. Pycnidia laminalia, conidiis bifusiformibus, brevibus, 5-7 µm longis. Typus generis: *Paraparmelia scotophylla* (Kurok.) Elix & Johnston.

Thallus foliose, saxicolous, adnate to loosely adnate, lobes subirregular, narrow (0.5) 1.0-3.0 (-4.0) mm wide, margins eciliate. Upper surface grey, often darkening with age, with a perforate polysaccharide covering. Medulla white. Underside pale tan to jet black, moderately to sparsely rhizinate, rhizines simple for the most part, sometimes tufted at the apices. Apothecia adnate, imperforate, spores ellipsoid, simple, 8 per ascus, 7-10 x 4-6 µm. Pycnidia laminal or subapical, conidia bifusiform. The cortex containing atranorin, rarely chloroatranorin or traces of usnic acid.

This genus currently contains the following species:

Paraparmelia adusta (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia adusta* Kurok., Bull. Natn. Sci. Mus., Tokyo, B, **11**, 77. 1985.

Paraparmelia alabamensis (Hale & McCull.) Elix & Johnston, comb. nov.
Basionym: *Parmelia alabamensis* Hale & McCull., Bryologist, **71**, 44. 1968.

Paraparmelia annexa (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia annexa* Kurok., in Hale & Kurokawa, Contrib. U.S. Nat. Herb., **36**, 151. 1964.

Paraparmelia arcana (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia arcana* Kurok. in Hale and Kurokawa, Contrib. U.S. Nat. Herb., **36**, 151. 1964.

Paraparmelia astricta (Brusse) Elix & Johnston, comb. nov.
Basionym: *Parmelia astricta* Brusse, Bothalia, **15**, 315. 1984.

Paraparmelia basutoensis (Hale) Elix & Johnston, comb. nov.
Basionym: *Parmelia basutoensis* Hale, Bryologist, **75**, 342. 1972.

Paraparmelia capnoides (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia capnoides* Kurok., Bull. Natn. Sci. Mus., Tokyo, B, 11, 78. 1985.

Paraparmelia cerussata (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia cerussata* Kurok., Bull. Natn. Sci. Mus., Tokyo, B, 11, 79. 1985.

Paraparmelia condyloides (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia condyloides* Kurok. in Hale, Bryologist, **75**, 343. 1972.

Paraparmelia conranensis (Elix) Elix & Johnston, comb. nov.
Basionym: *Parmelia conranensis* Elix, Aust. J. Bot., **29**, 20. 1981.

Paraparmelia fumigata (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia fumigata* Kurok., Bull. Natn. Sci. Mus., Tokyo, B, **11**, 81. 1985.

Paraparmelia interposita (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia interposita* Kurok., Bull. Natn. Sci. Mus., Tokyo, B, 11, 81. 1985.

Paraparmelia ischnoides (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia ischnoides* Kurok. in Hale and Kurokawa, Contr. U.S. Nat. Herb., **36**, 155. 1964.

Paraparmelia lecanoracea (Müll. Arg.) Elix & Johnston, comb. nov.
Basionym: *Parmelia lecanoracea* Mull. Arg., Flora, Jena **71**, 529. 1888.

Paraparmelia lithophila (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia lithophila* Kurok., Bull. Natn. Sci. Mus., Tokyo, B, **11**, 83. 1985.

Paraparmelia lithophiloides (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia lithophiloides* Kurok., Bull. Natn. Sci. Mus., Tokyo, B, **11**, 84. 1985.

Paraparmelia molybdiza (Nyl.) Elix & Johnston, comb. nov.
Basionym: *Parmelia molybdiza* Nyl., in Crombie, J. Bot. Brit. For., **14**, 19. 1876.

Paraparmelia mongaensis (Elix) Elix & Johnston, comb. nov.
Basionym: *Parmelia mongaensis* Elix, Aust. J. Bot., **29**, 22. 1981.

Paraparmelia murina (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia murina* Kurok., Bull. Natn. Sci. Mus., Tokyo, B, **11**, 85. 1985.

Paraparmelia nana (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia nana* Kurok., Bull. Natn. Sci. Mus., Tokyo, B, **1**, 86. 1985.

Paraparmelia neoquintaria (Hale) Elix & Johnston, comb. nov.
Basionym: *Parmelia neoquintaria* Hale, Smithonian Contr. Bot., **31**, 39. 1976.

Paraparmelia numinbahensis (Elix) Elix & Johnston, comb. nov.
Basionym: *Parmelia numinbahensis* Elix in Elix & Stevens, Aust. J. Bot., **27**, 877. 1979.

Paraparmelia owariensis (Asahina) Elix & Johnston, comb. nov.
Basionym: *Parmelia owariensis* Asahina, J. Jap. Bot., **28**, 135. 1953.

Paraparmelia prolata (Hale) Elix & Johnston, comb. nov.
Basionym: *Parmelia prolata* Hale, Bryologist, **75**, 344. 1972.

Paraparmelia pustulescens (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia pustulescens* Kurok. in Hale and Kurokawa, Contr. U.S. Nat. Herb., **36**, 156. 1964.

Paraparmelia rodriguesiana (Hue) Elix & Johnston, comb. nov.
Basionym: *Parmelia rodriguesiana* Hue, Nouv. Arch. Mus. Paris, ser. 3, 1, 167. 1899.

Paraparmelia rupicola (Lynge) Elix & Johnston, comb. nov.
Basionym: *Parmelia rupicola* Lynge, Akiv Bot., **13**, 132. 1914.
Paraparmelia schistacea(Kurok. & Filson) Elix & Johnston, comb. nov.
Basionym: *Parmelia schistacea* Kurok. & Filson, Bull. Natn. Sci. Mus., Tokyo, B, **1**, 44. 1975.
Paraparmelia scotophylla (Kurok.) Elix & Johnston, sp. nov.
Basionym: *Parmelia scotophylla* Kurok. in Kurokawa and Filson, Bull. Natn. Sci. Mus., Tokyo, B, **1**, 45. 1975.
Paraparmelia spodochroa (Kurok. & Filson) Elix & Johnston, comb. nov.
Basionym: *Parmelia spodochroa* Kurok. & Filson, Bull. Natn. Sci. Mus., Tokyo, B, **1**, 46. 1975.
Paraparmelia subtortula (Hale) Elix & Johnston, comb. nov.
Basionym: *Parmelia subtortula* Hale, Phytologia, **27**, 3. 1973.
Paraparmelia tortula (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia tortula* Kurok. in Hale and Kurokawa, Contr. U.S. Nat. Herb., **36**, 157. 1964.
Paraparmelia vanderbylii (Zahlbr.) Elix & Johnston, comb. nov.
Basionym: *Parmelia* vanderbylii Zahlbr., Ann. Cryptog. Exot., **5** 252. 1932.
Paraparmelia violacea (Kurok.) Elix & Johnston, comb. nov.
Basionym: *Parmelia violacea* Kurok. in Hale and Kurokawa, Contr. U.S. Nat. Herb., **36**, 158. 1964.
Paraparmelia xanthomelaena (Müll. Arg.) Elix & Johnston, comb. nov.
Basionym: *Parmelia xanthomelaena* Mull. Arg., Flora, Jena, **66**, 48. 1883.

Relicinopsis Elix & Verdon, gen. nov.

Thallus foliaceus, corticola adnatus, lobis sublinearibus vel linearibus, margines eciliatis, cortice superiore epicorticato, viridolutescens, acidum usnicum continens, subtus pallide brunneus vel brunneus, dense rhizinosus, rhizinis elongatis, simplicibus vel furcatis, concoloris. Apothecia adnata, imperforata, sporis octonis, ellipsoideis, 5-8 x 3-5 µm. Pycnidia marginalia raro laminalia, plus minusue extrusus, conidiis cylindricis vel raro fusiformibus, brevibus 5-7 µm longis.

Typus generis: *Relicinopsis intertexta* (Mont. & v.d. Bosch) Elix & Verdon.

Thallus foliose, corticolous, lobes sublinear to linear-elongate, narrow, 1.0-2.0 (-3.0) mm wide, with eciliate margins. Upper surface yellow-green, with a perforate polysaccharide covering. Medulla white. Underside pale tan to brown, densely rhizinate to the margins, rhizines elongate, simple or irregularly branched, concolorous with the lower surface. Apothecia adnate, imperforate, spores ellipsoid, simple, 8 per ascus, 5-8 x 3-5 µm. Pycnidia marginal rarely laminal, sometimes extruded, conidia cylindrical or fusiform. The cortex containing usnic acid and accessory atranorin.

This new genus includes four species:

Relicinopsis dahlii (Hale) Elix & Verdon, comb. nov.
Basionym: *Pseudoparmelia dahlii* Hale, Smithsonian Contrib. Bot., **31**, 28. 1976.
Relicinopsis intertexta (Mont. & v.d. Bosch) Elix & Verdon, comb. nov.
Basionym: *Parmelia intertexta* Mont. & v.d. Bosch in Montagne, Sylloge Gen. Spec. Cryptog., 327. 1856.

Relicinopsis malaccensis (Nyl.) Elix & Verdon, comb. nov.
Basionym: *Parmelia malaccensis* Nyl. in Nylander and Crombie, J. Linn. Soc. London, **20**, 52. 1883.

Relicinopsis rahengensis (Vain.) Elix & Verdon, comb. nov.
Basionym: *Parmelia rahengensis* Vain., Ann. Soc. Zool.-Bot. Fenn. Vanamo, 1, 39. 1921.

Acknowledgements

We wish to thank the Australian National University for generous financial assistance through the Faculties Research Fund and Dr. M.E. Hale for his continual encouragement, helpful and stimulating discussions, and assistance with type material.

References

Esslinger, T.L. (1977) A chemosystematic revision of the brown *Parmeliae*. Journ. Hattori Bot. Lab., **42**, 1-211.

Esslinger, T.L. (1978) A new status for the brown *Parmeliae*. Mycotaxon, **7**, 45-54.

Hale, M.E. Jr. (1974). New Combinations in the Lichen Genus *Pseudoparmelia* Lynge. Phytologia, **29**, 188-191.

Hale, M.E. Jr. (1976). A monograph of the Lichen Genus *Pseudoparmelia* Lynge (Parmeliaceae). Smithsonian Contrib. Bot., **31**, 1-62.

Hale, M.E. Jr. (1981). Pseudocyphellae and pored epicortex in the Parmeliaceae: their delimitation and evolutionary significance. Lichenologist **1**, 1-10.

Hale, M.E. Jr., (1986). *Flavoparmelia*, a new Genus in the Lichen Family Parmeliaceae (Ascomycotina) Mycotaxon, **25**, 603-605.

Hale, M.E. Jr., and Kurokawa, S. (1964). Studies on *Parmelia* subgenus *Parmelia*. Contrib. U.S. Nat. Herb., **36**, 121-191.

Krog, H. (1982a). Evolutionary trends in the foliose and fruticose lichens of the Parmeliaceae. Journ. Hattori Bot. Lab., **52**, 303-311.

Krog, H. (1982b). *Punctelia*, a new lichen genus in the Parmeliaceae. Nord. J. Bot., **2**, 287-292.

Krog, H. and Swinscow, T.D.V. (1979). *Parmelia* subgenus *Hypotrachyna* in East Africa. Norw. J. Bot., **26**, 11-43.

Kurokawa, S. (1985). Studies on Australian and Tasmanian Species of *Parmelia* (2), Bull. Natn. Sc. Mus., Tokyo, B, **11**, 77-90.

Lynge, B. (1914). Die Flechten der ersten Regnellschen Expedition. Die Gattungen *Pseudoparmelia* gen. nov. und *Parmelia* Ach. Arkiv for Botanik, **13**, 1-172.

Santesson, R. (1942). *Pseudoparmelia* Lynge, a Lichen Genus to be rejected. Svensk Botanisk Tidskrift, **36**, 471-474.

Vobis, G. and Hawksworth, D.L. (1981). Conidial Lichen-Forming Fungi in "Biology of Conidial Fungi" Vol 1, Ch 9, pp 245-272 (Academic Press, New York).

MYCOTAXON

Vol. XXVII, pp. 283-288 October-December 1986

TWO NEW DISCOMYCETES ON PINUS

A. FUNK

Pacific Forestry Centre
Canadian Forestry Service
506 W. Burnside Road
Victoria, B.C.
V8Z 1M5

ABSTRACT

Two new inoperculate discomycetes are described from *Pinus* in North America, viz., *Claussenomyces pini* sp. nov. from *P. contorta* Dougl., and *Crumenulopsis lacrimiformia* sp. nov. from *P. palustris* Mill.

INTRODUCTION

Collections of discomycetes received from widely separated locations in North America have presented an opportunity to describe two new bark-inhabiting species on *Pinus*. The first is from north-central British Columbia, Canada on lodgepole pine (*Pinus contorta* Dougl.) and the second is from central Florida, U.S.A. on longleaf pine (*Pinus palustris* Mill.). Both fungi are associated with disease in pine stems but their pathological status is not known.

TAXONOMY

Claussenomyces pini sp. nov. Fig. 1-4
Anamorphosum: *Dendrostilbella*-similis in agaro cultae

Apothecia atra, nitida, sessilia vel substipitata, singularia vel subcaespitosa, marginata, circularia vel undulata, ionomidotica, 0.2-0.8 mm diametro, usque ad 0.4

mm alto. Excipulum ex hyphis radiata composita; hyphis atro-viridia, gelatinosa, irregularia, 2-4 µm lata. Asci clavati, longistipitati, octospori, apices incrassatis, poro in iodo non caerulescenti, 85-105 x 8-10 µm. Ascosporae hyalinae, fusoideo-ellipsoideae, rectae vel leniter curvatae, 1-3 septatae, 10-18 x 3 µm, raro in ascis ascoconidia productae, sed in agaro ascoconidia numerosae. Ascoconidia hyalina, continua, ovoidea, 4 x 2 µm. Paraphyses filiformes, ramosae, ad apices leniter incrassata, epithecium fuscum formantibus.

Holotypus: in caulibus _Pinus_ _contorta_, Houston, B.C., Canada, January 1985, DAVFP 23301.

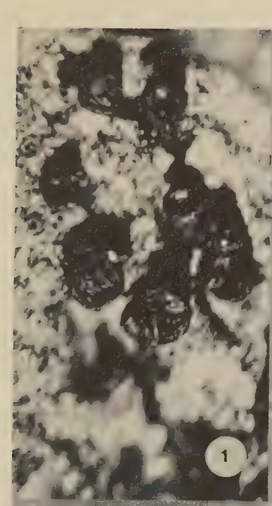
Apothecia black, shiny, sessile to substipitate, single or sub- caespitose, marginate, circular or undulate, ionomidotic, 0.2-0.8 mm diameter, up to 0.4 mm high. Excipulum composed of radiating hyphae; hyphae dark green, gelatinized, irregular, 2-4 µm diameter. Asci clavate, long-stalked, 8-spored, thickened apex, pore not staining in iodine, 85-105 x 8-10 µm. Ascospores hyaline, fusoid-ellipsoid, straight or slightly curved, 1-3 septate, 10-18 x 3 µm, rarely producing ascoconidia in the ascus, but abundantly on agar. Ascoconidia hyaline, continuous, ovoid, 4 x 2 µm. Paraphyses filiform, branching, slightly swollen at the tips and forming a dark epithecium.

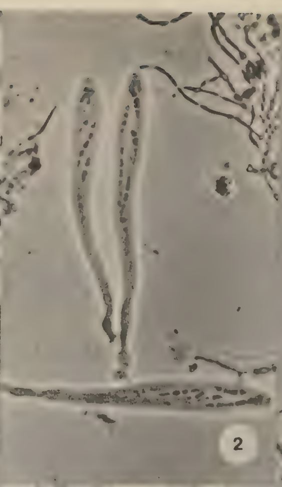
Holotype: in a stem of _Pinus_ _contorta_ Dougl. collected 20 km west of Houston, B.C., Canada in January 1985 by W.G. Bristow. DAVFP 23301.

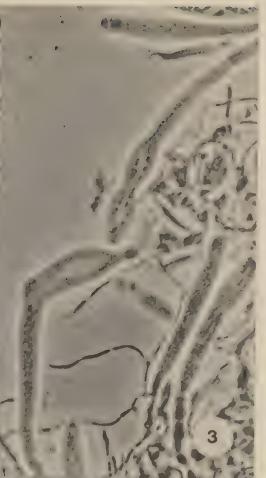
Claussenomyces _pini_ apothecia were found at the edge of a stalactiform rust canker (_Cronartium_ _coleosporioides_ Arth.) in January and were in prime condition. It would appear to be a secondary invader of diseased bark in this single known occurrence. The asci when mounted in dilute

---

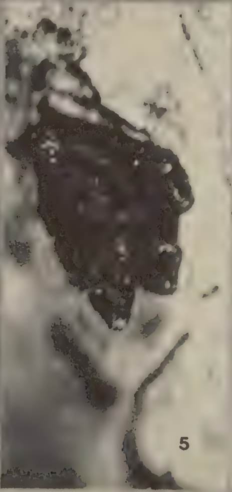
Figs. 1-4: _Claussenomyces_ _pini_ 1. Apothecia, habit on pine bark. X 88. 2. Asci and ascospores. X 572. 3. Asci mounted in dil. KOH showing extension of inner contents. X 572. 4. Germinating ascospores with ascoconidia. X 572. Figs. 5-8: _Crumenulopsis_ _lacrimiformia_ 5. Apothecia, habit on pine bark. X 88. 6. Asci and ascospores. X 572. 7. Apothecium, median section. X 242. 8. Excipular tissues. X 704.

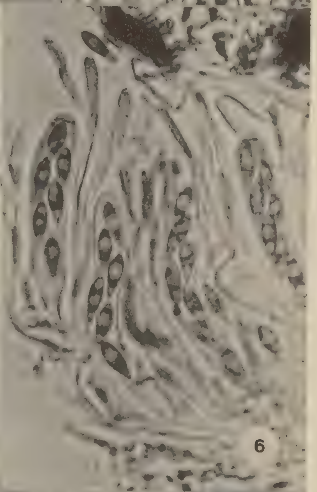

1

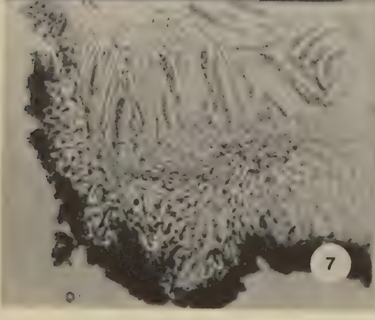

2

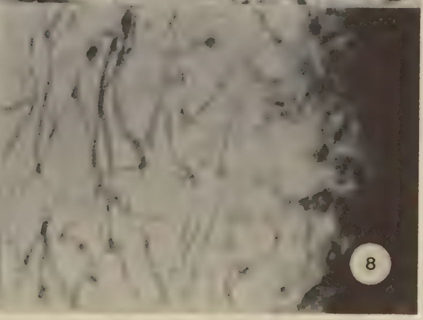

3

4


5


6


7


8

KOH extrude their contents in a manner resembling the action normally found in bitunicate asci (Fig. 3).

Cultural study

Cultures were readily obtained from ascospores shot from rehydrated apothecia onto malt agar. Ascospores germinated first by production of large quantities of ascoconidia giving the young colony a moist, yeast-like appearance. Ascospores and ascoconidia (Fig. 4) eventually produced germ tubes and the mycelial colony developed. Colonies were entirely appressed, sodden, almost colorless and with no diffusion zone. Optimum growth temperature was approximately 20°C at which the colony expanded 2.5 cm in 3 weeks. A strong antibiosis was noted against common mold contaminants in the plates. In 5 weeks the colony became yellowish brown and small synnemata developed. The synnemata were at first concolorous but later darkened with a hyaline droplet of conidia at the tip; they measured approximately 0.5 mm high and 0.5 mm wide. Conidia were rod-like, continuous and 2 x 0.8 µm.

Crumenulopsis _lacrimiformia_ sp. nov. (Figs. 5-8)

Apothecia erumpentia, singularia vel caespitosa, atro brunnea, circularia vel undulata, substipitata, gelatinosa, rugosa, hymenium flavida, 0.6-1.1 mm diametro. Excipulum medullosum subhyalina, _textura_ _epidermoidea_; excipulum ectalum atro brunnea, usque ad 20µm crassum, _textura_ _angularis_. Asci clavati, octospori vel quadrispori, poro in iodo non caerulescenti, 65-85 x 10-11 µm. Ascosporae hyaline, non septatae vel raro uniseptatae, guttulatae, lacrimiformae, 13-17 x 4-5 µm. Paraphyses simplices, filiformes, epithecium non formantibus, 2 µm crassa, ad apicem leniter incrassata.

Holotypus: DAVFP 23300, in rami _Pinus_ _palustris_ Mill. Gainesville, Florida, U.S.A., Aug. 11, 1985, J.D. Rogers.

Apothecia erumpent, single or caepitose, dark brown, circular or undulated, substipitate, roughened, gelatinized, hymenium pale yellow, 0.6-1.1 mm diameter. Medullary excipulum subhyaline, composed of _textura_ _epidermoidea_; ectal excipulum dark brown, approximately

20 µm thick, composed of textura angularis. Asci clavate, eight-spored or four-spored, pore not staining in iodine, 65-85 x 10-11 µm. Ascospores hyaline, non-septate or rarely one-septate, tear-drop shaped, 13-17 x 4-5 µm. Paraphyses simple, filiform, not forming an epithecium, approximately 2 µm wide, slightly swollen at the tips.

Holotype: DAVFP 23300, on dead tips of Pinus palustris Mill. near Gainesville, Florida, U.S.A., 11 Aug. 1985, collected by J.D. Rogers.
Isotype: WSP 67857.

DISCUSSION

The genus Claussenomyces Kirschst. was characterized as having green to black, gelatinized apothecia with J-asci and septate ascospores that "bud" in the ascus (Korf 1973; Dennis 1978). Dennis (1956) gave full descriptions of some species under the name Corynella Boud. which Korf and Abawi (1971) showed to be invalid. The new species appears to be closest to C. prasinulus (Karst.) Korf and Abawi (1971), having ascospores of similar size and septation, but C. prasinulus has emerald green apothecia and paraphyses that branch repeatedly at the tip.

Another species on pine, C. dacrymycetoideus Ouellette and Korf (1979), has 7-21-septate ascospores that bud prolifically in the ascus. It is possible that ascospores of the new species might bud more profusely in the ascus if allowed to mature further. Because the collection was made in mid-winter it is conceiveable that budding would recommence with the return of higher temperatures.

The genus Claussenomyces is also represented in British Columbia by C. pseudotsugae (Groves) Ouellette and Pirozynski (1974), a species occurring on Pseudotsuga, and by C. olivaceus (Fckl.) Sherwood (Hawksworth and Sherwood 1981) a resinicolous species on conifers. These two species have pycnidial anamorphs and are otherwise easily distinguished from C. pini on apothecial characters.

Crumenulopsis lacrimiformia was found on dead tips on pine branches in central Florida. No cultures were made. It is closest to C. pinicola (Fries) Groves (Groves 1969) but it is smaller throughout and has distinctive tear-drop shaped ascospores. The genus Crumenulopsis was placed in the family Dermateaceae by Korf (1973) and it was he who first suggested that this fungus might be a new species of Crumenulopsis. The structure and habit are very close to the other two species in the genus (Groves 1969) which also occur on pine.

ACKNOWLEDGEMENTS

I am indebted to Drs. J.D. Rogers and R.P. Korf for the Crumenulopsis collection and to Wen-ying Zhuang for preparing microsections; Dr. J.A. Parmelee kindly loaned collections from Herb DAOM; Mr. Leo Unger surveyed pine plantations for Clausssenomyces.

Dennis, R.W.G. 1956. A revision of the British Helotiaceae in the herbarium of the Royal Botanic Gardens, Kew, with notes on related European species. Commonweal. Mycol. Inst. Pap. No. 62, Kew.

Dennis, R.W.G. 1978. British ascomycetes. J. Cramer, Vaduz.

Groves, J.W. 1969. Crumenulopsis, a new name to replace Crumenula Rehm. Can. J. Bot. 47: 47-51.

Hawksworth, D.L. and M.A. Sherwood. 1981. A reassessment of three widespread resinicolous discomycetes. Can. J. Bot. 59: 357-372.

Korf, R.P. 1973. Discomycetes and Tuberales. in The Fungi, an advanced treatise 4A: 249-319. Academic Press, New York.

Korf, R.P. and G.S. Abawi. 1971. On Holwaya, Crinula, Claussenomyces, and Corynella. Can. J. Bot. 49: 1879-1883.

Ouellette, G.B. and K.A. Pirozynski. 1974. Reassessment of Tympanis based on types of ascospore germination within asci. Can. J. Bot. 52: 1889-1911.

Ouellette, G.B. and R.P. Korf. 1979. Three new species of Claussenomyces from Macaronesia. Mycotaxon 10: 255-264.

MYCOTAXON

Vol. XXVII, pp. 289-319 October-December 1986

A Comparison Between Phytophthora cryptogea and P. drechsleri

H. H. Ho and S. C. Jong

Department of Biology, State University of New York, New Paltz,
N.Y. 12561; Mycology & Botany Department, American Type
Culture Collection, 12301 Parklawn Drive, Rockville, MD 20852

Abstract

Considerable controversies exist in literature concerning the identification of a plant pathogen as Phytophthora cryptogea or P. drechsleri. Phytophthora drechsleri is believed to be distinguished from P. cryptogea primarily by its ability to grow well at 35 C and secondarily, by its occasionally homothallic behavior, larger oogonia and larger, more elongate sporangia with tapered base. Present study was undertaken to compare 19 isolates of P. cryptogea with 11 isolates of P. drechsleri (including the type and/or authentic cultures) from various hosts all over the world. Based on morphological and physiological characters, most isolates could not be recognized as "typical" P. cryptogea or P. drechsleri; they possess certain diagnostic features of both species. Growth at 35 C, alone or in combination with other criteria, could not separate these isolates into two distinct species. It appears most practical at this point, to merge P. drechsleri with P. cryptogea which has priority.

Introduction

Phytophthora cryptogea Pethybr. & Laff. is a common plant pathogen in the temperate regions attacking over 80 plant species from 23 families (45). First described on tomato (50), it is characterized by small hyphal swellings in clusters, ovoid to obpyriform, non-papillate, internally-proliferating sporangia, amphigynous antheridia and relatively small spherical oogonia. Tucker (68) recognized that the Phytophthora isolate from rotting potato tuber was similar to P. cryptogea but differed in the ability to grow well at 35 C, and thus a new species, P. drechsleri was erected. Later, Waterhouse (71) added that P. drechsleri could be further differentiated from P. cryptogea by the occasionally homothallic behavior, narrow hyphae, larger oogonia and larger, more elongated sporangia with tapered base. However, in practice, researchers often encountered great difficulty in deciding whether an isolate should be named P. cryptogea or P. drechsleri because the temperature criterion might not correlate with the morphological characters or the isolate has characteristics intermediate between these two species (18, 22, 27, 34, 41). Consequently, there was considerable confusion in literature concerning the identity of a pathogen being P. cryptogea or P. drechsleri. For example, the pathogen on sunflower, cucurbits and potato tubers, respectively, has been identified by some as P. cryptogea (35, 56, 57) but as P. drechsleri by the others (4, 14, 68). A researcher often reported both species associated with the same disease, as on Transvaal daisy (66), safflower (34), Douglas-fir (53) walnut (40) and cherry (43, 73). Nearly half of the plant species attacked by P. drechsleri are also hosts for P. cryptogea (9, 45, 64). Bumbieris (6) demonstrated that isolates of P. cryptogea and P. drechsleri had similar growth rate, hyphal diameter and sporangial shape and size and suggested the merging of these two species under P. cryptogea. The proposal has received support (12, 23, 26, 27, 41, 62) while some prefer to keep them as separate species (37, 40, 43, 53, 73). In view of the uncertainty, Keim et al. (33) identified the pathogen on Washington palm as belonging to P. drechsleri/cryptogea complex. Present study was undertaken to compare isolates of P. cryptogea and P. drechsleri from a variety of hosts all over the world to determine if these two species should be treated as synonymous or separate taxa.

Materials and Methods

Isolates and media. Specific information on the isolates of P. cryptogea and P. drechsleri used is given in Table 1. For crossing experiments, P. cinnamomi 32992 (A2), 32993 (A1), P. palmivora 26200 (A2), 26201 (A1) and P. nicotianae 38606 (A2) and 38607 (A1) were used. All isolates were obtained from the American Type Culture Collection (ATCC), Rockville, Maryland. Culture media used in various experiments included cleared V-8 agar (CV8), Difco cornmeal agar (CMA), and fresh corn meal (CA) agar as used by Tucker (68).

Table 1. Isolates of Phytophthora cryptogea and P. drechsleri used

Species	ATCC	Host	Origin	Source
P. cryptogea	15402	Aster sp.	Unknown	Gallegly N57 =CBS 308.62
	15403	Godetis sp.	S. Africa	Gallegly N56 =CBS 307.62
	28193	Pinus radiata (soil)	S. Australia	Bumbieris P10
	28194	Pinus radiata (soil)	S. Australia	Bumbieris P30
	34301	Pseudotsuga menziesii	Oregon	Pratt 37
	36226	Unknown	S. Australia	Halsall S121
	36229	Eucalyptus forest	Tasmania, Australia	Halsall D128
	36301	Potato	Ohio	Rowe 116
	44672	Garden Soil	S. Australia	Gerrettson-Cornell S121
	46518	Chrysanthemum morifolium	California	MacDonald Ph13
	46721(A)	Aster sp.	USA	Zentmyer P1088 =CBS 290.35

Table 1. (Continued)

Species	**ATCC**	**Host**	**Origin**	**Source**
P. cryptogea	46999	Grapevine	S. Africa	Marais 4
	48234	*Juniperus chinensis*	California	MacDonald 2-B
	48637	Unknown	Unknown	Warner
	52401	*Begonia-Elatior* hybrid	W. Germany	Kroeber 63651
	52402	*Solanum marginatum*	Ecuador	Kroeber 63689
	52403	*Begonia-Elatior* hybrid	W. Germany	Kroeber 63787
	52404	*Begonia Elatior* hybrid	W. Germany	Kroeber 64132
	56962(T)	*Lycopersicon esculentum*	Ireland	Ho H12.1 =CBS 113.19
P. drechsleri	10923	Unknown	USA	Jeffers
	15404	Citrus	California	Gallegly N112 =CMI 40532
	15428	Dalmatian insect flower	Unknown	Gallegly N111 =CMI 40499
	26756	*Carthamus tinctorius*	Unknown	Gother CMI 164.185
	28200	Safflower	Australia	Stovold GES 1
	34302	Douglas fir	Oregon	Roth 47
	44388	Pigeon pea	India	Erwin P2
	44389	Pigeon pea	India	Erwin P4
	46723	*Pinus radiata*	California	Zentmyer P1076
	46724(A)	*Beta vulgaris* var. *altissima*	USA	Zentmyer P1087 =CBS 292.35
	56192	*Cucumis sativa*	China	Ho, 518
	58424	*Cucumis sativa*	Iran	Ho, H13.1 = Ershad
	58425	*Lycopersicon esculentum*	Japan	Ho, H13.2 = Miyata LER 811
	58597	Unknown	Japan	Ho, H13.6 = Yu 51

ATCC-Identified by American Type Culture Collection accession number
CBS -Centraalbureau voor Schimmelcultures, Baarn, Netherlands
CMI -Commonwealth Mycological Institute, Kew, Surrey, England
A -Authentic culture
T -Type culture

Morphology: Colony characteristics on CV8, CMA, and CA were compared after incubating in darkness at 20 C for 7 days. The colony diameters on CV8 were measured at right angle through the inoculum and the width of primary hyphae measured under light microscope. The minimal and maximal temperatures for growth were tested by growing them on CV8 and CMA at 5 C and 35 C. Sporangia were produced by incubating small mycelial agar discs of CV8 in freshly collected stream water sterilized by filtration through 0.45 µm pore size millipore membrane discs and incubating under light at 20 C. Production of sex organs in single cultures was followed on CV8 supplemented with sitosterol (30 mg/l) by examining them periodically under microscope through the bottom of the petri dish. If the isolate failed to produce sex organs readily in single culture, it was paired with the appropriate mating types of *P. cinnamomi*, *P. cryptogea*, *P. drechsleri*, *P. nicotianae* or *P. palmivora*. In case of a successful mating, the ability of the isolate to produce sex organs by selfing was confirmed by pairing it with the compatible strain across a polycarbonate membrane to prevent physical contact between the cultures (36). They were examined for sex organs after 3-4 wk incubation in dark at 20 C. To induce chlamydospore formation, small mycelial agar discs were submerged in 15 ml sterile distilled water in 19 x 150 mm test tubes, and incubated in dark at 15 C for 5 wk.

Ability to grow on malt extract agar: Isolates were grown on Difco malt extract solidified with 1.5% Bacto agar. Colony diameters were measured after 6 days.

Pigment production: Isolates were grown on Timmer's medium (55). Production of pigment in the medium was determined after 2 wk at 20 C in the dark.

Growth response to malachite green: Malachite green was added to CMA at a concentration of 1:18,000,000. Colony diameters were measured after 6 days.

Ability to utilize nitrate nitrogen: Isolates were grown on Ribeiro's synthetic agar medium (55) minus asparagine so that nitrate nitrogen was the only nitrogen source. Colony diameter was determined after 6 days.

Pathogenicity to apple: Apple fruit (McIntosh) was inoculated through artifical wound which was then sealed with Scotch tape and enclosed in a plastic bag. Results were determined after incubation at 20 C for 2 wk.

Results

Colony morphology: Colony morphology of the isolates on CV8 ranged from slightly fluffy to fairly fluffy with no distinct growth pattern. The edge of colony was slightly diffuse and irregular. Colonies were mainly appressed on CMA. Most isolates of *P. cryptogea* and about half of isolates of *P. drechsleri* produced luxuriant aerial mycelium on fresh corn meal agar medium. The primary hyphae on CV8 were uniform, measuring 5-7µm wide, though the branches might be uneven. Network or chains of small spherical to irregular hyphal swellings (<25 µm) were often produced in water, or on membranes in crossing experiments.

Sporangium: Sporangia were produced readily in water within 24-48 hr by all isolates except *P. cryptogea* isolates ATCC 48234 and ATCC 56962 which did not sporulate until 4-5 days later. In all cases, the sporangia were non-deciduous and non-papillate and internal prolifetion was seen at least in some sporangia. The apex of sporangium often flattened on mounting and the empty sporangia collapsed partially after zoospore release. Sporangia were mainly obpyriform, ovoid to elongate, with tapered or rounded base in varying proportions (Table 2). Repeated emergence of zoospores was observed in ATCC 52403 and ATCC 52404 of *P. cryptogea* and ATCC 58597 of *P. drechsleri.*

Sex organs: Despite numerous attempts, *P. drechsleri* isolate ATCC 28200 did not produce any sex organs whereas ATCC 34302 only mated with A1 mating type of *P. nicotianae* to form *nicotianae* -type oongia. The production of sex organs by other isolates are summarized in Table 3. Oogonia were spherical to subspherical with no tapered base, though the oogonial stalk was sometimes tapered within the antheridium. Oospores were plerotic in all isolates filling the oogonia to varying extent, except in the selfing of ATCC 15428 of *P. drechsleri* in old cultures. The free space between the oogoum wall and the oospore inside is represented by the following formula:

$$\text{Free oogonial space} = \frac{\text{Oogonium diam - oospore diam} \times 100\ (\%)}{\text{Oogonium diam}}$$

The thickness of oospore wall (2-5 μm) relative to the oospore size is expressed as follows:

$$\text{Relative oospore thickness} = \frac{\text{Outer oospore diam - inner oospore diam} \times 100\ (\%)}{\text{Outer oospore diam}}$$

In general, oogonia produced by selfing of heterothallic isolates were larger, developed pigmentation earlier and more intensely than those formed in crossings, but they often aborted, devoid of properly developed oospores. In crossing with *P. cinnamomi,* both large *cinnamomi* -type and smaller *cryptogea/drechsleri* - type oogonia were produced. Antheridia were short cylindrical, mostly unicellular. Bicellular antheridia were occasionally found especially among isolates of *P. drechsleri* or in crosses with *P. cinnamomi.*

Chlamydospores: No chlamydospores could be found in any isolate of *P. cryptogea* or *P. drechsleri.*

Physiology: All isolates produced very slight pigmentation in Timmer's medium except ATCC 15403 and ATCC 48637 of *P. cryptogea* and ATCC 15428 of *P. cryptogea* which formed moderate brown coloration. They grew well on malt agar medium, tolerated malachite green and utilized inorganic nitrate readily. With the exeption of ATCC 15404 of *P. drechsleri,* all isolates caused lesions in apple fruit.

Table 2. Growth, hyphal diameter and sporangial characters of *Phytophthora cryptogea* and *P. drechsleri* isolates

Species	ATCC	Growth at		Hyphal diam.(a) (µm)	Sporangium(c)			
		5 C	35 C		Type of base(b)	Length(L) (µm)	Breadth(B) (µm)	L/B ratio
P. cryptogea	15402	--	--	6-7	R	49 ± 7	32 ± 5	1.6 ± 0.2
	15403	--	+/-	6-7	R/T	52 ± 10	27 ± 4	2.0 ± 0.2
	28193	--	--	5-6	R	45 ± 9	29 ± 3	1.5 ± 0.2
	28194	--	--	5-6	R	35 ± 6	24 ± 6	1.4 ± 0.1
	34301	++	+/-	5-6	R/T	61 ± 7	36 ± 5	1.7 ± 0.2
	36226	++	--	5-6	R/T	52 ± 7	29 ± 3	1.8 ± 0.2
	36229	++	--	5-6	R/T	54 ± 5	31 ± 3	1.7 ± 0.2
	36301	++	--	5-6	R	46 ± 3	33 ± 2	1.4 ± 0.1
	44672	--	--	5-6	R	49 ± 5	29 ± 3	1.7 ± 0.2
	46518	--	+/-	6-7	R/T	63 ± 10	31 ± 4	2.3 ± 0.4
	46721	++	--	6-7	R	54 ± 6	35 ± 4	1.6 ± 0.2
	46999	++	--	5-6	R	51 ± 6	31 ± 4	1.7 ± 0.2
	48234	--	--	6-7	R	38 ± 6	28 ± 4	1.4 ± 0.2
	48637	--	++	6-7	R	35 ± 6	23 ± 3	1.4 ± 0.2
	52401	++	--	5-6	R	57 ± 7	35 ± 4	1.6 ± 0.2
	52402	--	--	5-6	R/T	50 ± 7	30 ± 5	1.7 ± 0.3
	52403	++	--	6-7	R/T	52 ± 6	33 ± 4	1.6 ± 0.2
	52404	++	--	6-7	R	57 ± 7	35 ± 4	1.6 ± 0.2
	56962	+/-	--	6-7	R	38 ± 7	23 ± 3	1.7 ± 0.2
P. drechsleri	10923	+/-	--	6-7	R	48 ± 6	31 ± 4	1.6 ± 0.2
	15404	--	--	5-6	R/T	56 ± 13	24 ± 3	2.3 ± 0.6
	15428	--	++	5-6	R/T	40 ± 9	24 ± 4	1.7 ± 0.4
	26756	--	+/-	5-6	R	48 ± 4	32 ± 3	1.5 ± 0.1
	28200	--	--	6-7	R	58 ± 9	31 ± 4	1.8 ± 0.3
	34302	++	--	6-7	R	60 ± 8	32 ± 6	2.0 ± 0.4

Table 2. (Continued)

Species	ATCC	Growth at 5 C	Growth at 35 C	Hyphal diam.(a) (μm)	Type of base(b)	Sporangium(c) Length (L) (μm)	Sporangium(c) Breadth (B) (μm)	Sporangium(c) L/B ratio
P. drechsleri	44388	--	++	5-6	R/T	47 ± 6	28 ± 5	1.7 ± 0.2
	44389	+/-	++	5-6	R/T	43 ± 7	25 ± 4	1.8 ± 0.3
	46723	+/-	+/-	6-7	T	62 ± 15	26 ± 5	1.6 ± 0.3
	46724	--	++	6-7	R/T	34 ± 7	22 ± 3	1.6 ± 0.3
	56192	--	++	5-6	T	71 ± 10	29 ± 4	2.5 ± 0.5
	58424	--	++	5-6	T	63 ± 9	28 ± 6	2.3 ± 0.5
	58425	++	--	6-7	R/T	49 ± 7	28 ± 4	1.8 ± 0.2
	58597	--	+/-	6-7	R/T	52 ± 11	25 ± 5	2.1 ± 0.4

(a) Primary hyphae measured
(b) Dominant type of sporangial base: R (round), T (tapered), R/T (round and tapered in varying proportions)
(c) Mean ± standard error, based on 50 measurements

Table 3. Morphology of sex organs *Phytophthora cryptogea* and *P. drechsleri* isolates

Species ATCC	Oogonium diam (μm)	Oospore diam (μm)	Free oogonial space (%) (a)	Relative oospore wall thickness (%) (b)	Antheridium(c) Length (μm)	Antheridium(c) width (μm)
P. cryptogea ATCC 15402 (A1)						
I. Selfed on membrane X *palmivora* 26200	39 ± 3	33 ± 3	32	43	13 ± 2	13 ± 2
II. X *cryptogea* 52401	30 ± 3	26 ± 3	25	47	14 ± 2	14 ± 2

Table 3. (Continued)

Species	Oogonium diam(μ m)	Oospore diam(μm)	Free oogonial space(%)(a)	Relative oospore wall thickness(%)(b)	Antheridium(c) Length(μm)	Antheridium(c) width(μm)
ATCC						
X *cryptogea* 36226	28 ± 2	26 ± 2	16	47	15 ± 3	13 ± 1
X *cryptogea* 36301	27 ± 2	23 ± 2	38	45	15 ± 3	13 ± 2
X *cryptogea* 48234	30 ± 2	25 ± 2	31	42	15 ± 3	15 ± 2
X *cryptogea* 48637	34 ± 3	29 ± 3	28	44	12 ± 2	14 ± 2
X *cryptogea* 52401	30 ± 3	26 ± 3	25	47	14 ± 2	14 ± 2
X *cinnamomi* 32992(d)	28 ± 2	25 ± 2	20	54	15 ± 2	15 ± 2
av. all crossings	30	26	27	47	14	14
Overall mean for isolate	34.5	29 ± 5	29.5	45	13.5	13.5
ATCC 15403 (A2)						
X *cryptogea* 46721	32 ± 2	28 ± 2	24	45	13 ± 2	15 ± 2
ATCC 28193 (A2)						
X *cryptogea* 46721	30 ± 2	25 ± 2	31	48	15 ± 2	14 ± 2
X *cinnamomi* 32993	29 ± 2	26 ± 2	20	47	15 ± 3	13 ± 2
Overall mean for isolate	29.5	25.5	25.5	47.5	15	13.5
ATCC 28194 (A2)						
I. Selfed on membrane	32 ± 2	29 ± 2	23	44	15 ± 2	14 ± 1
X *cryptogea* 46721(e)						
II. X *cryptogea* 46721(e)	30 ± 2	26 ± 2	25	47	15 ± 2	13 ± 1
X *cinnamomi* 32993	30 ± 3	26 ± 3	25	41	16 ± 4	13 ± 2
Av. all crossing	30	26	25	44	15.5	13
Overall mean for isolate	31	27.5	24	44	15	13.5

Table 3. (Continued)

Species ATCC	Oogonium diam(μm)	Oospore diam(μm)	Free oogonial space(%)(a)	Relative oospore wall thickness(%)(b)	Antheridium(c) Length(μm)	Antheridium(c) width(μm)
ATCC 34301 (A2)						
X *cryptogea* 46721	29 ± 1	23 ± 2	37	32	14 ± 2	13 ± 1
X *cinnamomi* 32993	33 ± 4	29 ± 3	23	26	16 ± 3	16 ± 2
Overall mean for isolate	31	26	30	29	15	14.5
ATCC 36226 (A2)						
X *cryptogea* 15402	28 ± 2	26 ± 2	16	47	15 ± 3	13 ± 1
X *cinnamomi* 32993(e)	29 ± 2	25 ± 2	26	42	16 ± 3	14 ± 2
Overall mean for isolate	28.5	25.5	21	44.5	15.5	13.5
ATCC 36229 (A2)						
X *cryptogea* 46721	30 ± 2	26 ± 2	31	42	14 ± 2	14 ± 2
X *cryptogea* 56962	28 ± 2	24 ± 2	27	56	14 ± 3	13 ± 2
X *cinnamomi* 32993	28 ± 2	24 ± 1	27	37	18 ± 5	14 ± 1
Overall mean for isolate	29	25	29	45	15	14
ATCC 36301 (A2)						
I. Selfed on membrane						
X *cryptogea* 46721	40 ± 2	34 ± 2	28	46	12 ± 2	14 ± 2
X *cinnamomi* 32993	38 ± 3	33 ± 2	25	38	15 ± 2	15 ± 2
Selfed in single culture	37 ± 2	32 ± 2	33	39	15 ± 3	14 ± 2
Av. all selfings	38	33	29	41	14	14
II. X *cryptogea* 46721	34 ± 4	29 ± 3	23	42	15 ± 3	14 ± 2
X *cinnamomi* 32993	34 ± 2	30 ± 2	27	37	15 ± 2	14 ± 2
Av. all crossings	34	29.5	25	39.5	15	14
Overall mean for isolate	36	31	27	40	14.5	14

Table 3. (Continued)

Species ATCC	Oogonium diam(μm)	Oospore diam(μm)	Free oogonial space(%)(a)	Relative oospore wall thickness(%)(b)	Antheridium(c) Length(μm)	Antheridium(c) width(μm)
ATCC 44672 (A2)						
X *cryptogea* 46721	29 ± 2	25 ± 2	26	42	15 ± 2	14 ± 1
ATCC 46518 (A2)						
X *drechsleri* 44388	38 ± 4	32 ± 3	30	39	14 ± 3	15 ± 2
ATCC 46721 (A1)						
I. Selfed on membrane						
X *cryptogea* 15403(e)	35 ± 3	30 ± 5	27	46	13 ± 3	14 ± 2
X *cryptogea* 28193(e)	34 ± 2	29 ± 1	27	37	11 ± 2	11 ± 1
X *cryptogea* 28194	32 ± 2	27 ± 2	29	56	16 ± 2	13 ± 2
X *cryptogea* 36301	32 ± 2	27 ± 2	29	40	13 ± 2	13 ± 2
X *cryptogea* 44672	33 ± 4	28 ± 3	28	38	16 ± 2	15 ± 3
X *cryptogea* 52401	32 ± 2	27 ± 2	33	45	14 ± 2	14 ± 2
X *cryptogea* 52403	31 ± 2	27 ± 2	24	40	14 ± 2	14 ± 2
Selfed in single culture(e)	36 ± 3	31 ± 3	26	40	12 ± 2	13 ± 2
Av. all selfings	33	28	30	43	14	13
II. X *cryptogea* 15403	32 ± 2	28 ± 2	24	45	13 ± 2	15 ± 2
X *cryptogea* 28193	30 ± 2	25 ± 2	31	48	15 ± 2	14 ± 2
X *cryptogea* 28194	30 ± 2	26 ± 2	25	47	15 ± 2	13 ± 1
X *cryptogea* 34301	29 ± 1	23 ± 2	37	32	14 ± 2	13 ± 2
X *cryptogea* 36229	30 ± 2	26 ± 2	31	42	14 ± 2	14 ± 2
X *cryptogea* 36301	34 ± 4	29 ± 3	23	42	15 ± 3	14 ± 2
X *cryptogea* 44672	29 ± 2	25 ± 2	26	42	15 ± 2	14 ± 1
X *cryptogea* 46999	30 ± 2	25 ± 2	31	42	14 ± 2	13 ± 2
X *cryptogea* 52401	33 ± 2	28 ± 2	28	57	16 ± 3	14 ± 2
X *cryptogea* 52403	31 ± 3	26 ± 2	30	47	13 ± 2	14 ± 2

Table 3. (Continued)

Species	Oogonium diam(μm)	Oospore diam(μm)	Free oogonial space(%)(a)	Relative oospore wall thickness(%)(b)	Antheridium(c)	
					Length(μm)	width(μm)
ATCC						
X *cryptogea* 52404(e)	32 ± 2	27 ± 2	37	40	15 ± 3	15 ± 2
X *cinnamomi* 32992	29 ± 1	25 ± 1	26	54	14 ± 2	14 ± 3
X *drechsleri* 15404	32 ± 2	27 ± 3	29	45	14 ± 2	14 ± 2
X *drechsleri* 46723	31 ± 2	26 ± 3	30	28	14 ± 3	14 ± 2
Av. all crossings	31	26	29	44	14	14
Overall mean for isolates	32	27	29.5	43.5	14	13.5
ATCC 46999 (A2)						
X *cryptogea* 46721	30 ± 2	25 ± 2	31	42	14 ± 2	13 ± 2
ATCC 48234 (A2)						
X *cryptogea* 15402	30 ± 2	25 ± 2	31	42	15 ± 3	15 ± 2
ATCC 48637 (A2)						
I. Selfed on membrane						
X *cryptogea* 15402(e)	34 ± 3	28 ± 4	32	44	13 ± 2	13 ± 2
X *cinnamomi* 32993	34 ± 4	27 ± 4	38	50	11 ± 2	12 ± 1
Av. all selfings	34	27.5	35	47	12	12.5
II. X *cryptogea* 15402	34 ± 3	29 ± 3	28	44	12 ± 2	14 ± 2
X *cinnamomi* 32993	32 ± 2	28 ± 2	28	49	12 ± 2	14 ± 2
Av. all crossings	33	28.5	28	46.5	14	14
Overall mean for isolate	33.5	28	31.5	47	13	13
ATCC 52401 (A2)						
I. Selfed on membrane						
X *cinnamomi* 32993(e)	30 ± 3	27 ± 3	19	56	12 ± 1	15 ± 2

Table 3. (Continued)

Species	Oogonium diam(µm)	Oospore diam(µm)	Free oogonial space(%)(a)	Relative oospore wall thickness(%)(b)	Antheridium(c) Length(µm)	Antheridium(c) width(µm)
ATCC						
II. × *cryptogea* 15402	30 ± 3	26 ± 3	25	47	14 ± 2	14 ± 2
× *cryptogea* 46721	33 ± 3	28 ± 2	28	57	16 ± 3	14 ± 2
× *cryptogea* 56962	28 ± 2	25 ± 2	27	43	12 ± 2	13 ± 1
× *cinnamomi* 32993	27 ± 2	23 ± 2	38	39	18 ± 2	14 ± 2
Av. all crossings	29.5	25.5	29.5	46.5	15	14
Overall mean for isolate	30	26	24	51	13.5	14
ATCC 52402 (A2)						
× *cryptogea* 46721	29 ± 3	24 ± 4	32	44	15 ± 3	14 ± 2
× *cinnamomi* 32993	29 ± 2	25 ± 2	26	42	16 ± 3	14 ± 2
Overall mean for isolate	29	24.5	29	43	15.5	14
ATCC 52403 (A2)						
× *cryptogea* 56962	29 ± 2	26 ± 2	20	47	14 ± 3	14 ± 2
× *cinnamomi* 32993	28 ± 2	24 ± 2	27	37	15 ± 3	15 ± 2
Overall mean for isolate	28.5	25	23.5	42	14.5	14.5
ATCC 52404 (A2)						
× *cryptogea* 46721	32 ± 2	27 ± 2	37	40	15 ± 3	15 ± 2
× *cinnamomi* 32993	29 ± 2	24 ± 2	32	37	14 ± 2	13 ± 2
Overall mean for isolate	30.5	25.5	34.5	38.5	14.5	14
ATCC 56192 (A1)						
I. Selfed on membrane						
× *palmivora* 26200	32 ± 2	27 ± 2	37	50	12 ± 2	13 ± 1

Table 3. (Continued)

Species ATCC	Oogonium diam(μm)	Oospore diam(μm)	Free oogonial space(%)(a)	Relative oospore wall thickness(%)(b)	Antheridium(c) Length(μm)	Antheridium(c) width(μm)
II. X *cryptogea* 36229	28 ± 2	25 ± 2	27	43	12 ± 2	13 ± 1
X *cryptogea* 52401	28 ± 2	25 ± 2	27	43	12 ± 2	13 ± 1
X *cryptogea* 52403	29 ± 2	26 ± 2	20	47	14 ± 2	24 ± 2
X *cinnamomi* 32992	29 ± 2	25 ± 3	20	54	13 ± 3	13 ± 1
X *drechsleri* 15404	28 ± 3	25 ± 3	20	54	13 ± 3	13 ± 1
Av. all crossings	28	25	24	50	13	13
Overall mean for isolate	30	26	30.5	50	12.5	13
P. drechsleri						
ATCC 10923 (Homothallic)						
Selfed in single culture	34 ± 3	28 ± 3	32	38	14 ± 2	13 ± 2
ATCC 15404 (A2)						
X *drechsleri* 56192(e)	30 ± 3	26 ± 2	32	38	15 ± 2	16 ± 1
X *cryptogea* 56962(e)	28 ± 3	25 ± 3	20	54	13 ± 3	13 ± 1
X *cryptogea* 46721	32 ± 2	27 ± 3	29	45	14 ± 2	14 ± 2
Overall mean for isolate	30	26	27	46	14	14
ATCC 15428 (A1)						
I. Selfed on membrane(e)						
X *drechsleri* 58597	38 ± 5	32 ± 6	29	57	10 ± 2	12 ± 2
Selfed in single culture(e)	41 ± 8	34 ± 7	52	44	12 ± 2	15 ± 3
Av. all selfings	39.5	33	40.5	50.5	11	13.5
II. X *drechsleri* 58597	40 ± 4	35 ± 4	23	36	13 ± 2	14 ± 2
X *cinnamomi* 32992(e)	32 ± 3	27 ± 4	29	45	16 ± 4	25 ± 3
Av. all crossings	36	31	26	41	14.5	14.5
Overall mean for isolate	38	32	33	46	13	14

Table 3. (Continued)

Species ATCC	Oogonium diam(μm)	Oospore diam(μm)	Free oogonial space(%)(a)	Relative oospore wall thickness(%)(b)	Antheridium(c)	
					Length(μm)	width(μm)
ATCC 26756 (A2)						
I. Selfed on membrane						
× *drecshleri* 58425	34 ± 2	30 ± 2	22	48	14 ± 2	14 ± 2
II. × *drechsleri* 46724	28 ± 5	24 ± 5	21	44	15 ± 3	14 ± 2
× *drechsleri* 56192	26 ± 3	23 ± 3	22	45	12 ± 2	13 ± 1
× *drechsleri* 58424	26 ± 2	21 ± 2	35	42	17 ± 4	15 ± 2
× *drechsleri* 58425	29 ± 2	25 ± 2	20	48	13 ± 3	14 ± 3
× *drechsleri* 58597	29 ± 5	25 ± 2	26	36	18 ± 3	17 ± 3
Av. all crossings	28	24	25	43	15	15
Overall mean for isolate	31	27	23.5	45.5	14.5	14.5
ATCC 44388 (A1)						
I. Selfed on membrane						
× *cinnamomi* 32992	42 ± 4	36 ± 4	27	40	14 ± 3	15 ± 2
× *palmivora* 26200	41 ± 3	33 ± 4	35	38	13 ± 2	15 ± 2
Av. all selfings	41.5	34.5	31	39	13.5	15
II. × *drechsleri* 46724	35 ± 4	29 ± 5	35	37	13 ± 3	14 ± 3
× *drechsleri* 58597	32 ± 5	26 ± 4	34	47	15 ± 4	15 ± 2
× *cinnamomi* 32992	35 ± 2	29 ± 3	31	20	17 ± 3	16 ± 3
Av. all crossings	34	28	33	35	15 ± 1	15 ± 1
Overall mean for isolate	38	31	32	37	14	15
ATCC 44389 (A1)						
I. Selfed on membrane						
× *cinnamomi* 32992	31 ± 3	27 ± 3	24	45	13 ± 2	14 ± 2

Table 3. (Continued)

Species ATCC	Oogonium diam(μm)	Oospore diam(μm)	Free oogonial space(%)(a)	Relative oospore wall thickness(%)(b)	Antheridium(c) Length(μm)	Antheridium(c) width(μm)
II. X *drechsleri* 46723	36 ± 4	30 ± 4	31	36	11 ± 2	14 ± 2
X *drechsleri* 46724	36 ± 2	31 ± 2	22	40	13 ± 2	14 ± 2
X *drechsleri* 58597	35 ± 4	29 ± 4	31	37	13 ± 3	14 ± 2
X *drechsleri* 32992	33 ± 2	28 ± 2	23	42	15 ± 3	17 ± 2
Av. all crossings	35	29.5	27	39	13	15
Overall mean for isolate	33	28	25.5	42	13	14.5
ATCC 46723 (A2)						
X *drechsleri* 44389(e)	36 ± 4	30 ± 4	31	36	11 ± 2	14 ± 2
X *cryptogea* 46721	31 ± 2	26 ± 3	30	28	14 ± 3	14 ± 2
Overall mean for isolate	33.5	28	30.5	27	12.5	14
ATCC 46724 (A2)						
I. Selfing on membrane						
X *cinnamomi* 32993	32 ± 3	28 ± 3	23	44	12 ± 2	13 ± 2
II. X *drechsleri* 26756	28 ± 5	24 ± 5	21	44	15 ± 3	14 ± 2
X *drechsleri* 44388	36 ± 3	29 ± 4	35	37	14 ± 2	15 ± 2
X *drechsleri* 44389	36 ± 2	31 ± 2	22	40	13 ± 2	14 ± 2
X *drechsleri* 58425	32 ± 2	26 ± 3	34	52	14 ± 2	14 ± 2
X *drechsleri* 58597	32 ± 3	27 ± 2	29	45	12 ± 3	12 ± 1
X *cinnamomi* 33993(e)	32 ± 1	25 ± 1	39	36	17 ± 3	14 ± 2
Av. all crossings	33	28	29	41	14	14
Overall mean for isolate	32.5	27.5	26.5	43	13	13.5
ATCC 56192 (A1)						
I. Selfed on membrane						
X *sinensis* 46538(e)	31 ± 3	26	30	35	16 ± 3	16 ± 2

Table 3. (Continued)

Species	Oogonium diam (μm)	Oospore diam (μm)	Free oogonial space (%) (a)	Relative oospore wall thickness (%) (b)	Antheridium (c) Length (μm)	Antheridium (c) width (μm)
ATCC						
II. X *drechsleri* 15404	30 ± 3	26 ± 2	25	35	15 ± 2	16 ± 1
X *drechsleri* 26756	26 ± 3	23 ± 3	22	45	12 ± 2	13 ± 1
X *drechsleri* 58597	27 ± 2	22 ± 2	34	40	20 ± 2	19 ± 2
Av. all crossings	28	24	27	40	16	16
Overall mean for isolate	29.5	25	28.5	37.5	16	16
ATCC 58424 (A2)						
I. Selfed in single culture	31 ± 2	27 ± 2	24	40	16 ± 3	15 ± 2
II. X *drechsleri* 26756	26 ± 2	21 ± 2	35	42	17 ± 4	15 ± 2
X *cinnamomi* 33993	26 ± 2	22 ± 2	28	40	16 ± 4	15 ± 2
Av. all crossings	26	21.5	32	41	16.5	15
Overall mean for isolate	28.5	24	28	40.5	16	15
ATCC 58425 (A1)						
X *drechsleri* 26756	29 ± 2	25 ± 2	20	48	13 ± 3	14 ± 3
X *drechsleri* 46724	32 ± 2	26 ± 3	34	52	14 ± 2	14 ± 2
X *drechsleri* 58597	32 ± 5	27 ± 4	29	40	19 ± 4	16 ± 3
X *cinnamomi* 33992	28 ± 2	24 ± 2	27	50	15 ± 3	14 ± 2
Overall mean for isolate	30	26	27.5	47.5	15	14.5
ATCC 58597 (A2)						
I. Selfed on membrane						
X *drechsleri* 15428	34 ± 3	29 ± 3	27	37	17 ± 4	16 ± 2
Selfed in membrane	40 ± 3	36 ± 3	19	35	19 ± 4	20 ± 3
Av. all selfings	37	32.5	23	36	18	18

Table 3. (Continued)

Species	ATCC	**Oogonium diam(µm)**	**Oospore diam(µm)**	**Free oogonial space(%)(a)**	**Relative oospore wall thickness(%)(b)**	**Antheridium(c) Length(µm)**	**Antheridium(c) width(µm)**
II. X *drechsleri*	15428	40 ± 4	35 ± 4	23	36	13 ± 2	14 ± 2
X *drechsleri*	26756	29 ± 5	25 ± 2	26	36	18 ± 3	17 ± 3
X *drechsleri*	44388	32 ± 5	26 ± 4	34	47	15 ± 4	15 ± 2
X *drechsleri*	44389	35 ± 4	29 ± 4	31	37	13 ± 3	14 ± 2
X *drechsleri*	56192	27 ± 2	22 ± 2	34	40	20 ± 2	19 ± 2
X *drechsleri*	58425	32 ± 5	27 ± 4	29	40	19 ± 4	16 ± 3
Av. all crossings		33	28	28.5	39.5	16 ± 3	15 ± 2
Overall mean for isolate		35	30	26	38	17	16.5

(a) Free oogonial space = $\frac{\text{Oogonium diam-oospore diam}}{\text{Oogonium diam}} \times 100$

(b) Oospore wall/oospore. diam = $\frac{\text{outer oospore diam-inner diam}}{\text{Outer oospore diam}} \times 100$ (%)

(c) Mean ± standard error, based on 50 measurements

(d) Only small *cryptogea* type oogonia measured

(e) Less than 50 measurements due to paucity of fully developed oogonia and oospores

Discussion

For the sake of comparison, the overall means of sporangia and sex organs of all *P. cryptogea* and *P. drechsleri* isolates used in present study are summarized in Table 4 and the published data on these two species in Table 5.

Tucker (68) erected *P. drechsleri* primarily based on its high maximal temperature for growth. A review of the published literature revealed that some isolates of *P. cryptogea* with morphological characteristics typical for the species grew at or above 35 C (6, 18, 34, 41, 54), and not all isolates of *P. drechsleri* prefer high temperature for growth (6, 46, 53, 59). In present study, out of 16 isolates of *P. drechsleri* five did not grow at all and 3 showed only traces of growth at 35 C. On the other hand, at least one isolate of *P. cryptogea* grew well and 3 isolates had slight growth at this temperature. *Phytophthora drechsleri* is supposed to stop growing at 10 C (68) or 5 C (71) while the minimal temperature for growth for *P. cryptogea* is under 1 C (71) or under 5 C (68). In present study, about half of the *P. cryptogea* isolates failed to grow whereas 5 out of 14 isolates of *P. drechsleri* showed good or marginal growth at 5 C. Such discrepancy also existed in literature (5, 6, 34, 43, 53, 66). It is not clear if the isolates used in this study have undergone any change since initial isolation but if they did, it merely shows that the temperature threshold difference may not be a stable taxonomic character.

Newhook *et al.* (44) distinguished *P. cryptogea* with broad hyphae (>8 μm diam) from *P. drechsleri* with narrow hyphae (<8μm diam). Waterhouse (71) described the hyphae of *P. cryptogea* as very uneven, up to 8μm and those of *P. drechsleri* as fairly uniform, not often over 5 μm wide. Present study demonstrated that the primary hyphae of both species were mostly uniform, 5-7μm wide. Similarly, Bumbieris (6) found no significant difference in the hyphal width between these two species. Published literature shows that the hyphal width of *P. cryptogea* was under 8μm, similar to *P. drechsleri*. In fact, Waterhouse and Blackwell (72) described the mycelium of *P. cryptogea* in the British Isles as fine (3 to 5 μm wide).

One of the major reasons why Waterhouse (71) kept *P. cryptogea* separate from *P. drechsleri* is that the former produces smaller sporangia (37-40 μm long) compared with the larger sporangia (36-50 μm long) in the latter. We found that the overall sporangial length of all *P. cryptogea* isolates studied is slightly but not significantly smaller than that of *P. drechsleri* isolates (49 ± 8 vs 52 ± 10 μm) because of the great variations in measurements, especially among isolates of *P. drechsleri*. It is hard to compare our results with the published data, because of the different conditions under which they were produced, but the mean values of the sporangial length were 30-62 μm for *P. cryptogea* and 29-64μm for *P. drechsleri* ,(Table 5) suggesting again that the difference in sporangial size is not significant enough to separate the two species.

Most researchers consider the sporangia of *P. drechsleri* more elongated than those of *P.cryptogea* (16). To certain extent, this difference is confirmed in present study which shows the overall L/B

Table 4. Over 11 mean of measurements of sporangia and sex organs of *P. cryptogea* and *P. drechsleri* isolates

Species	Sporangium Length (μm)	Sporangium Breadth	Sporangium L/B ratio	Oogonium diam (μm)	Oospore diam (μm)	Free Oogonial space (%)(a)	Relative(b) Oospore wall thickness (%)	Antheridium Length (μm)	Antheridium width (μm)
P. cryptogea	49 ± 8(c)	30 ± 4	1.7 ± 0.2	31(d) ± 3	27 ± 2	29 ± 3	43 ± 5	14 ± 1	14 ± 1
				34(e) ± 3	29 ± 3	29 ± 6	46 ± 5	13 ± 1	14 ± 1
				31(f) ± 2	26 ± 2	28 ± 3	43 ± 4	14 ± 1	14 ± 1
P. drechsleri	52 ± 10	28 ± 3	1.9 ± 0.3	33(d) ± 3	28 ± 2	28 ± 3	41 ± 5	14 ± 1	15 ± 1
				35(e) ± 4	30 ± 3	28 ± 6	42 ± 5	14 ± 2	15 ± 2
				32(f) ± 3	27 ± 3	28 ± 6	40 ± 5	15 ± 1	15 ± 1

(a) Free oogonial space = $\frac{\text{Oogonium diam-oospore diam}}{\text{Oogonium diam}} \times 100$ (%)

(b) Oospore wall/oospore diam = $\frac{\text{Outer oospore-diam-inner oospore diam}}{\text{Outer oospore diam}} \times 100$ (%)

(c) Mean standard error
(d) Both selfed and crossing (e) Selfed only (f) crossing only

Table 5. Characteristics of *Phytophthora cryptogea* and *P. drechsleri* isolates recorded in literature chronologically

Species	Ref.	Host of isolate	Hyphal diam (μm)	Growth at 5C	Growth at 35	Sporangium Length	Sporangium L/B ratio	Oogonium diam (μm)	Oospore diam (μm)	Antherdium Length (μm)
P. cryptogea	50	Tomato				40	1.5(a)	30	25	
	3	Tulip				31/34	1.4/1.5	29	24	
		Unknown				40	1.5	28/30	23/25	
	19	Tulip				25	1.3(a)	30	24	
	68	Tomato		++	--	37	1.7(a)	26	23	
	38	Tomato			--			24		

Table 5. (Continued)

Species	Ref.	Host of isolate	Hyphal diam(μm)	Growth at 5 C	Growth at 35	Sporangium Length	Sporangium L/B ratio	Oogonium diam (μm)	Oospore diam(μm)	Antherdium Length(μm)
P. cryptogea	66	Transvaal daisy		--	--	32	1.9(a)			
	70	*Godetia* sp.	5	++		35	1.5(a)	38	34/35	12/15
	42	*Gloxinia*		++	--	35	1.7	25	22	
	63	Onion						32		
		Unknown						27		
	72	Unspecified	3-5		--	30/37	1.5/1.9(a)	30	25	16
	21	*Populus simonii*	6.5		--	45	1.6	22-30	24	
	60	Unknown			--				24	
	47	*Gerbera* sp.				(31-45)	1.6			
	71	Unspecified	8	++	--	37-40	1.7	30-32		
	17	Endive			--	34	1.5			
	8	Tomato				(16-67)				
		Callistephus chinensis				(24-93)				
		Solanum melongenae				(18-83)				
	14	*Solanum melongenae*				39-49	1.4-1.4	29	26	19
	51	Lupin				46	1.6			
	57	Cucurbits				(32-41)	1.3-1.5	20-26		
	18	Bean	8		++					
	6	*Callistephus hortensis*	6	--	--	39	1.5(a)			
		Pine soil	4	+/-	+/-	45	1.4(a)			
		Apricot soil	4	+/-	+/-	48	1.4(a)			
	53	Douglas fir		++	--					
	25	African daisy		++	--	31	1.3(a)			
	69	*Solanum melongenae*	7-9	++	--	36	1.4			

Table 5. (Continued)

Species	Ref.	Host of isolate	Hyphal diam (μm)	Growth at 5 C	Growth at 35	Sporangium Length	Sporangium L/B ratio	Oogonium diam (μm)	Oospore diam (μm)	Antherdium Length (μm)
P. cryptogea										
	56	Potato			+/-					
	34	Safflowe	6.2	--	++	44	1.2(a)			
	44	Unspecified	8				1.6	28-40	25-30	
	41	Alfalfa soil		++	++	54	1.7			
	23	*Pinus radiata*			--	47-52	1.4-1.6			
	24	*Garden soil*				48/51	1.6/1.4			
		Pinus radiata				47/49	1.5			
		Eucalyptus pilularis				50	1.4			
		Malus sylvestris				52	1.4			
	54	*Gerbera* sp.		++	++					
		Begonia sp.		++	++					
	37	*Begonia* sp.		++	--	47	1.5-1.6(a)	29-33	27-31	
		Solanum marginatum		++	--	46	1.5(a)	29-32	28	
		Gypsophila paniculata		++	--	38	1.5(a)	28	26	
		Gerbera jamesonii		++	--	37-40	1.5-1.7(a)	27-32	25-28	
		Spinacia oleracea		++	--	43	1.5(a)	29-33	26-31	
		Callistephus chinensis		++	--	40	1.6(a)			
		Beta vulgaris var. *altissima*		++		39	1.6(a)			
	27	Firs		++	--	62	1.6(a)	35	29	
		Sugar pine		+/-	+/-	57	1.5(a)	40	30	
	73	Cherry		--	++	41	1.3(a)			
P. drechsleri	68	*Solanum tuberosum*		--	++	31	1.5(a)	31	26	variable
	38	*Potato*			++					
	65	Sugar beet			++	36/39	1.4(a)	35	29	10-14

Table 5. (Continued)

Species	Ref.	Host of isolate	Hyphal diam (μm)	Growth at 5 C	Growth at 35	Sporangium Length	Sporangium L/B ratio	Oogonium diam (μm)	Oospore diam (μm)	Antherdium Length (μm)
P. drechsleri	20	Chrysanthemum cinenariefolum			++	50	1.8	29-34	25-30	11-13
		Celosia plumosa								
		Schinus								
		Solanum lycopersicum								
	15	Safflower		--	++					
	32	Watermelon		--	++	43	1.5	28	21	14
	70	Unspecified	5	--	++	36-50	1.2-1.9(a)	36		14-15
	59	Safflower		++or+/-						
		Sugarbeet			+/-					
	22	Pepper			++					
	13	Cucurbita pepo		--	++					
	48,49	Pigeon pea	3-6	--	++	17-22		(23-27)	30	12
	51	Lupin				54	1.7(a)			
	14	Carthamus tinctorin	6	--	++	40	1.5			
		Beta vulgaris	6	--	++	40-54	1.3-1.7	40	30-33	16-17
		Cucurbits	5-7	--	++	37-64	1.6-1.9	25-37	23-30	16-20
		Helianthus annus	5			41/42	1.5			
		Cicer arietnum				39	1.4	40	26	18
	62	Forest soils		(++,+/-or--)						
	46	Cassava		--	--	(35-52)				
	53	Douglas fir		++	--					
	43	Cherry	6	++	++	49	1.8(a)			
	34	Safflower	5			(56-79)				
	5	Citrus	5	--	++	(36-50)	1.2-1.9(a)			
	44	Unspecified	6				1.6	(28-50)	(20-40)	

Table 5. (Continued)

Species	Ref.	Host of isolate	Hyphal diam (μm)	Growth at 5 C	Growth at 35	Sporangium Length	Sporangium L/B ratio	Oogonium diam (μm)	Oospore diam (μm)	Antherdium Length (μm)
P. drechsleri	1	Cantaloupe	4	--	++	56	1.7(a)	30		17
	23	Unknown				49	1.4			
	6	*Chrysanthemum cineranifolium*	4		++	40	1.5(a)			
		Soil	4		+/-	49	1.3(a)			
		Safflower	4-5		+/-	40	1.4(a)			
		Gooseberry	4		+/-	40	1.4(a)			
	31	Pigeon pea		--	++	54-66	1.5-1.7	31-43	19-38	13-24
	39	Melon	Thick			51	1.6			
	37	Cucumber			++	48	1.5(a)	33	28	
		Beta vulgaris			++	40	1.4(a)	40	31	
	30	Cucurbits	5-7	--	++	29-61	1.7-2.1	29-35	25-30	17-23

(a) Calculation based on author's data
(b) Data in parenthesis represent range in measurements; no mean vae given

ratio to be 1.7 ± 0.2 for P. cryptogea isolates and 1.9 ± 0.3 for P. drechsleri isolates but the difference can hardly be adequate to distinguish these two species, especially in view of the overlapping ranges: 1.4-2.0 and 1.4-2.3 respectively. Both oval/obpyriform type and elongated type sporangia were present in isolates of these two species, but the latter type was more common in P. drechsleri isolates. The overlapping ranges were also reflected in literature by the average L/B ratios reported: 1.2-1.9 for P. cryptogea and 1.2-2.1 for P. drechsleri (Table 5). Although most of the sporangia of P. drechsleri in Tucker's diagram (68) were elongated, this feature was not mentioned in his species description and it is not clear if elongated sporangia indeed characterized this species. Based on Tucker's original data (68), the L/B ratio of sporangium in P. drechsleri was 1.5, the same as that of P. cryptogea as given by Pethybridge and Lafferty (50) and even less than that determined by Tucker himself (1.7). Thus, it is unlikely that the elongated sporangium was used by Tucker as a diagnostic character to differentiate P. drechsleri from P. cryptogea. Waterhouse (71) described the sporangia of P. drechsleri as "very variable in shape from broadly obpyriform to elongated obpyriform".

Wilcox and Mircetich (73) and Chitzanidis and Koyeas (8) considered the tapering base of the sporangium as a key character in distinguishing P. drechsleri from P. cryptogea which has rounded base. Present study showed that while tapered base was more common among isolates of P. drechsleri, it was also present in P. cryptogea isolates and many isolates produced sporangia with rounded or tapered base in varying proportions. Both rounded and tapered bases were figured by Tucker for P. drechsleri (68) while Waterhouse (71) referrred to the sporangia of P. drechsleri as "sometimes tapering at the base".

Waterhouse (71) noted that the sporangia of P. cryptogea often has a conspicuous central vacuole. We have observed such vacuoles in many isolates of P. drechsleri and P. cryptogea and they do not seem to be characteristic of P. cryptogea only. In fact, a central vacuole is shown in every sporangium of P. drechsleri figured by Tucker (68). Gerrettson-Cornell (23, 24) found central vacuoles only in sporangia that failed to germinate by zoospores.

Another key character used by Waterhouse (71) and Krober (37) to separate P. cryptogea from P. drechsleri is the oogonial size which is smaller in the former (30-32 vs 36 μm diam). The oogonial size was not discussed when Tucker (68) erected P. drechsleri as a new species. His measurement of oogonia of P. drechsleri (av. 31.3 μm diam) was slightly larger but very close to that given by Pethybridge and Lafferty (50) for P. cryptogea (av. 30μm diam). Other researchers reported the average oogonial diameters to be 20-40 μm for P. cryptogea and 25-43μm for P. drechsleri (Table 5). In present study, the overall mean oogonial size of P. drechsleri (33 ± 3 μm diam) was slightly but not significantly larger than that of P. cryptogea (31 ± 3μm diam) and the range of variation was the same (28.5 -38μm diam) for both species. Furthermore, when oogonia formed by selfing alone or by crossing alone were considered there was hardly any difference in the oogonial diameters between P. cryptogea and P. drechsleri (34 ± 3 vs 35 ± 4 and 31 ± 2 vs 31.5 ± 3 μm diam, respectively). In general, as reported earlier in P.

cinnamomi (29), the oogonia produced by selfing in present study were larger than those formed in dual cultures and they developed pigmentation more rapidly and more intensely. It is important for taxonomic studies to induce the formation of sex organs in single isolate culture. Unfortunately, we found out that although a heterothallic isolate mated readily with a compatible partner on agar medium, it often failed to produce any or only a few fully developed oogonia with oospores when they were separated physically by a polycarbonate membrane. This was especially true for isolates of *P. cryptogea.* It appears that while sex organs may be formed by selfing when two compatible strains are crossed in dual cultures, the possibility of hybridization cannot be dismissed (22, 63).

Newhook *et al.* (44) considered the oospore wall thickness of *P. cryptogea* relative to the oospore diameter a particularly important diagnostic character. Present study compared the percentage of the oospore diameter occupied by the oospore wall and found that the difference too small (43+5 % and 41+5 %, respectively) and the range overlapping too much (29-51% and 27-47.5 % respectively) to differientiate *P. cryptogea* from *P. drechsleri.*

According to Waterhouse (71), the antheridia of *P. cryptogea* are shorter than those of *P. drechsleri* (10 and 14-15 µm, respectively), but she and Blackwell (72) earlier described the antheridia of *P. cryptogea* from the British Isles as "spherical, 16 m in diameter". No measurement of the antheridia was given in the original descriptions of *P. cryptogea* (50) and *P. drechsleri* (68), although Tucker described the antheridia of the latter as "variable". Other reseachers reported the antheridia to be 12-19 µm long in *P. cryptogea* and 10-24 µm long in *P. drechsleri.* We found the overall antheridia of *P. drechsleri* to be slightly longer than that of *P. cryptogea* (15 ± 1 and 14 ± 1 m, respectively) but again the difference is too small and the range overlapped (13-16.5 and 13-15.5 µm, respecively) so that this character cannot be used as a dependable taxonomic criterion. Although long, becellular antheridia were more often found in isolates of *P. drechsleri,* the occurrence was too erratic to be of significance in differentiating these two species.

Waterhouse (71) further noted that whereas *P. cryptogea* is heterothallic, producing oospores rapidly and abundantly with *P. cinnamomi, P. drechsleri* may be homothallic or heterothallic but would not mate with *P. cinnamomi.* Our observation confirmed earlier reports (31, 52, 58, 61, 62) that isolates of *P. drechsleri* could mate with *P. cinnamomi* whereas some isolates of *P. cryptogea* failed to produce sex organs when crossed with *P. cinnamomi.* It is difficult to distinguish *P. cryptogea* and *P. drechsleri* based on sexual behavior. Both species behaved heterothallically (58) and although homothallic isolates are more common for *P. drechsleri* they have been reported for *P. cryptogea* as well (57). Leonian (38) distinguished *P. cryptogea* from *P. drechsleri* because the former but not the latter produced sex organs from sterile mycelium when transferred from pea broth to distilled water, implying homothallism in *P. cryptogea.* In present study, all isolates were heterothallic except ATCC 10923 of *P. drechsleri.* *Phytophthora drechsleri* isolate ATCC 58424 produced sex organs in single culture within two weeks but formed them more abundantly and more rapidly when mated with the compatible strain. It is not known whether any of the heterothallic isolates studied was homothallic when freshly isolated, but some isolates of *P. drechsleri* from cucumber were homothallic initially and then changed to heterothallic condition (Ho, unpublished).

Although chlamydospores of *P. drechsleri* have been reported on plant roots and hypocytyls (2,10,11), these structures could not be found in culture, despite diligent search among all isolates of *P. cryptogea* and *P. drechsleri.* Pal *et al.* (48) reported chlamydospores produced *in situ* by *P. drechsleri* var. *cajani,* but based on their diagrams, the structures considered as chlamydospores should be interpreted as hyphal swellings because they were not cut off from the rest of the mycelium.

In cultural characteristics, isolates of *P. cryptogea* and *P. drechsleri* were very similar especially on CV8 and CMA. Physiologically, they were indistinguishable in the ability to grow on malt extract agar, to utilize inorganic nitrate, to tolerate malachite green and in the pigment production. Pathologically, they all caused lesions on apple fruits within two weeks. The only exception, ATCC 15404 of *P. drechsleri* which failed to grow on apple fruit despite numerous attempts, could have degenerated as it also showed unusually slow growth compared with other isolates.

In summary, there is no reliable taxonomic character to differentiate *P. cryptogea* from *P. drechsleri.* When the isolates were plotted based on the most important criteria used: mean sporangial length, mean oogonial diameter and growth at 35 C, it was not possible to separate them into distinct *cryptogea* group nor *drechsleri* group. The majority of isolates had certain characteristics of both species. Thus, isolate ATCC 10923 of *P. drechsleri* produced rather large oogonia abundantly and promptly in single culture but formed smaller, obpyriform to ovoid sporangia with rounded base and failed to grow at 35 C. Isolate ATCC 58424 of *P. drechsleri* produced large, elongated sporangia with tapered base, grew well at 35 C but the oogonia were small. Isolate ATCC 48637 of *P. cryptogea* produced small, obpyriform sporangia with rounded base but grew well at 35 C and formed rather large oogonia. It can be argued that some of these could be hybrids. On the other hand, in view of the large number of intermediate forms, the most practical solution at this point is to merge *P. drechsleri* with *P. cryptogea* which has priority. The merging of these two species was proposed more than 30 years ago by Bywater and Hickman (7) who noticed the similarity between *P. cryptogea, P. drechsleri, P. erythroseptica, P. himalayensis* (=*P. erythroseptica* sensu Waterhouse) and *P. richardiae* and suggested grouping them together as one species: *P. erythroseptica.* Bumbieris (6) raised this issue again by proposing to treat *P. cryptogea* and *P. drechsleri* as conspecific. The similarity between the two species was further substantiated by electrophoresis pattern of soluble protein (41) and serology (26). Our study substantiated the claim that *P. drechsleri* cannot be specificially differentiated from *P. cryptogea.* We feel that one of the major problems in *Phytophthora* taxonomy is that there are too many species to be distinguished by too few taxonomic characters which are too easily affected by cultural conditions. At least, one way to solve the problem is to compare many isolates of all Phytophthora species under standard conditions to determine if some of these "species" could be consolidated. Although we do not subscribe to Leonian's notion (38) that there are only three good species of Phytophthora, Ribeiro's estimate (55) of "only a dozen or so valid species" does not appear to be such a "radical view" either. Differences between "species" can often be attributable to adaptation, physiological specialization or hybridization, and should be treated as morphological variation within a taxon. Thus, although morphological differentiation existed in host-specialized groups of P. megasperma (28), it was viewed only as a consequence of isolation due to host specialization. A similar situation probably exists here for P. cryptogea. Thus "P. drechsleri" can be considered as a high temperature variant of P. cryptogea adapted to plant hosts of warmer areas and along with this change, minor modifications in morphological characteristics as well. We prefer to refrain from a formal re-description of P. cryptogea until many isolates of other related species are studied to determine if any further regrouping might be necessary.

Acknowledgement

This work was supported in part by a grant from the SUNY New Paltz Grants for Research and Creative Program to H.H. Ho and NSF Grant BSR 8413523 to S. C. Jong.

The authors thank Li Luo and Laura Palmisans for their invaluable technical assistance and Elmer E. Davis for reviewing the manuscript.

Literature Cited

1. Alavi, A., and Strange, R.N. 1979. A baiting technique for isolating Phytophthora drechsleri, causal agent of crown rot of Cucumis species in Iran. Plant Dis. Rep. 63: 1084-1086.
2. Alavi, A., and Strange, R.N. 1982. The relative susceptibility of some cucurbits to an Iranian isolate of Phytophthora drechsleri. Pl. Pathol. 31: 221-227.
3. Ashby, S.F. 1929. Further note on the production of sexual organs in paired cultures of species and strains of Phytophthora. Trans. Br. Mycol. Soc. 14: 255-260.
4. Banihashemi, Z. 1975. Phytophthora black stem rot of sunflower. Plant Dis. Rep. 59: 721-724.
5. Boccas, B., and Laville, E. 1978. Les maladies a' Phytophthora des agrumes. Inst. Herches sur les Fruits et Agrumes (IRFA). 77 pp.
6. Bumbieries, M. 1974. Characteristics of two Phytophthora species. Aust. J. Bot. 22: 655-660.
7. Bywater, J., and Hickman, C.J. 1959. A new variety of Phytophthora erythroseptica, which causes a soft rot of pea roots. Trans. Br. Mycol. Soc. 42: 513-524.
8. Chitzanidis, A., and Koyeas, H. 1970. Notes on Greek species of Phytophthora II. Ann. Inst. Phytopathol. Benaki, N.S. 9: 267-274.

9. Cother, E.J. 1975. *Phytophthora drechsleri:* Pathogenicity testing and determination of effective host range. Aust. J. Bot. *23:* 87-94.
10. Cother, E.J., and Griffin, D.M. 1973b. Formation of chlamydospores by *Phytophthora drechsleri.* Trans. Br. Mycol. Soc. *61:* 379-402.
11. Cother, E.J., and Griffin, D.M. 1973b. The role of alternate hosts in survival of *Phytophthora drechsleri.* Aust. J. Biol. Soc. *26:* 1109-1113.
12. Duniway, J.M. 1976. Movement of zoospores of *Phytophthora cryptogea* in soils of various textures and matric potentials. Phytopathology *66:* 877-882.
13. El-Helaly, A.F., Asawah, M.W., Elarosi, H.M., and Wasfy, E.H. 1968. Fruit rots of vegetable marrow in Egypt (United Arab Republic). Phytopathol. Mediterr. *7:* 107-115.
14. Ershad, D. 1971. Beitrag zur Kenntnis der *Phytophthora* Arten in Iran und ihrer phytopathologischer Bedeutung. Mitt. Biol. BundAnst. Ld. u. Forstw. 140. 84 pp.
15. Erwin, D.C. 1952. *Phytophthora* root rot of safflower. Phytopathology *42:* 32-35.
16. Erwin, D.C. 1983. Variability within and among species of *Phytophthora.* Pages 149-165, in: *Phytophthora* Its Biology, Taxonomy, Ecology and Pathology. D.C. Erwin, S. Bartnicki-Garcia and P.H. Tsao, (Ed.) Am. Phytopathol. Soc., St. Paul, MN. 392 pp.
17. Forlot, P., Harranger, H., Payen, J., and Schwinn, F.J. 1966. *Phytophthora cryptogea* Pethybr. et Laff., nouvel agent de la pourriture des endives (*Cichorium intybus* L. var. *foliosum* Hegi) en cours des forcage. Phytopathol. Z. *56:* 1-18.
18. Flowers, R.A., Erwin, D.C., and Hendrix, J.W. 1973. Isolation of *Phytophthora cryptogea* from bean in Kentucky. Plant Dis. Rep. *57:* 170-191.
19. Foister, C.E. 1930. Blossom blight and shanking of tulips. Gardener's Chronicle *87:* 171-172.
20. Frezzi, M.J. 1950. Las especies de *"Phytophthora"* en la Argentina Rev. Invest. Agric. *4:* 47-133.
21. Frezzi, M.J. 1957. *"Phytophthora cryptogea,"* causante de la muerte de *"Populus simonii"* en mendoza (Argentina). Rev. Argen. Agron. *24:* 136-143.
22. Galindo, J.A., and Zentmyer, G.A. 1967. Genetical and cytological studies of *Phytophthora* strains pathogenic to pepper plants. Phytopathology *57:* 1300-1304.
23. Gerrettson-Cornell, L. 1979. Notes on the morphology of five isolates of *Phytophthora cryptogea* Pethyb. and Laff. from Australia. Phyton (Argen.) *37:* 105-118.
24. Gerrettson-Cornell, L. 1980. Notes on the morphology of some isolates of *Phytophthora* from Australia. Cryptog. Mycol. *1:* 139-154.
25. Gill, H.S., Zentmyer, G.A., Ribeiro, O.K., and Klure, L.J. 1976. A *Phytophthora* disease of African daisies (*Osterspermum* spp.) in California. Plant Dis. Rep. *60:* 647-649.
26. Halsall, D.M. 1976. Specificity of cytoplasmic and cell-wall antigens from four species of *Phytophthora.* J. Gen. Microbiol. *94:* 149-158.

27. Hamm, P.B., and Hansen, E.M. 1982. Pathogenicity of *Phytophthora* species to Pacific Northwest Conifers. Eur. J. For. Pathol. 12: 167-174.
28. Hansen, E.M., and Hamm, P.B. 1983. Morphological differentiation of host-specialized groups of *Phytophthora megasperma*. Phytopathology 73: 129-134.
29. Ho, H.H., and Zentmyer, G.A. 1977. Morphology of *Phytophthora cinnamomi*. Mycologia 69: 701-713.
30. Ho, H.H., Lu Jiayun, and Gong Longyin. 1984. *Phytophthora drechsleri* causing blight of *Cucumis* species in China. Mycologia 76: 115-121.
31. Kannaiyan, J., Ribeiro, Erwin, D.C., and Nene, Y.L. 1980. *Phytophthora* blight of pigeon pea in India. Mycologia 12: 169-181.
32. Katsura, K. 1958. A *Phytophthora* rot of watermelon caused by *Phytophthora drechsleri* Tucker. Sci. Rep. Fac. Agric. Saikyo Univ. 10: 77-85.
33. Keim, R., Klure, L.J., and Zentmyer, G.A. 1979. Collar rot of Washington palms in containers. Plant Dis. Rep. 63: 718-720.
34. Klisiewicz, J.M. 1977. Identity and relative virulence of some heterothallic *Phytophthora* species associated with root and stem rot of safflower. Phytopathology 67: 1174-1177.
35. Klisiewicz, J.M., and Beard, B.H. 1976. Diseases of sunflower in California. Plant Dis. Rept. 60: 298-301.
36. Ko, W.H. 1978. Heterothallic *Phytophthora*: Evidence for hormonal regulation of sexual reproduction. J. Gen. Microbiol. 107: 15-18.
37. Kroeber, H. 1981. Vergleichende untersuchungen vom grundtyp *Phytophthora cryptogea* und *P. drechsleri* abweichender isolate. Phytopathol. Z. 102: 219-231.
38. Leonian, L. H. 1934. Identification of *Phytophthora* species. W.Va. Agric. Exp. Stn. Bull. 262 36p.
39. Maden, S., and Karahan, O. 1980. A new root and foot-rot disease of melons (*Phytophthora drechsleri* Tucker) in central Anatolia and its pathogenicity on common melon cultivars in this region. J. Turkish Phytopathol. 9: 49-55.
40. Matheron, M.E., and Mircetich, S.M. 1985. Pathogenicity and relative virulence of *Phytophthora* spp. from walnut and other plants to rootstocks of English walnut trees. Phytopathology 75: 977-981.
41. Matsumoto, N., and Sato, T. 1979. *Phytophthora cryptogea* Pethyb. & Laff. found in alfalfa-field soil. Ann. Phytopathol. Soc. Jpn. 45: 362-368.
42. Middelton, J.T., Tucker, C.M., and Tompkins, C.M. 1944. A disease of gloxinia caused by *Phytophthora cryptogea*. J. Agric. Res. 68: 405-413.
43. Mircetich, S.M., and Matheron, M.E. 1976. *Phytophthora* root and crown rot of cherry trees. Phytopathology 66: 549-558.
44. Newhook, F.J., Waterhouse, G.M., and Stamps, D.J. 1978. Tabular key to the species of *Phytophthora* de Bary. Commonw. Mycol. Inst. Mycol. Pap. 143. 20 pp.
45. Novotelnova, N.S. 1974. The genus *Phytophthora*. Soviet Acad. Botanical Institute, Leningrad, USSR. 208 pp.
46. Oliveros, B., Lozano, J.C., and Booth, R.H. 1974. A *Phytophthora* root rot of cassava in Colombia. Plant Dis. Rep. 58: 703-705.

47. Pag, H. 1960. Untersuchungen uber das "Gerbera Sterben." Nachrichtenbl. Dtsch. Pflanzenschutzd. (Braunschweig) 12: 74-77.

48. Pal, M., Grewal, J.S., and Sarbhoy, A.K. 1970. A new stem rot of arhar caused by Phytophthora: Indian Phytopathol. 25: 583-597.

49. Pal, M., and Grewal, J.S. 1975. Physiological studies on Phytophthora drechsleri var. cajani. Indian Phytopathol. 28: 479-482.

50. Pethybridge, G.H., and Lafferty, H.A. 1919. A disease of tomato and other plants caused by a new species of Phytophthora. Sci. Proc. R. Dublin Soc. (N.S.) 15: 487-505.

51. Pratt, B.H., and Heather, W.A. 1972. Method for rapid differentiation of Phytophthora cinnamomi from other Phytophthora species isolated from soil by lupin baiting. Trans. Br. Mycol. Soc. 59: 87-96.

52. Pratt, B.H., and Heather, W.A. 1973. Recovery of potentially pathogenic Phytophthora and Pythium spp. from native vegetation in Australia. Aust. J. Biol. Sci. 26: 575-582.

53. Pratt, R.G., Roth, L.F., Hansen, E.M., and Ostrofsky, W.D. 1976. Identity and pathogenicity of species of Phytophthora causing root rot of Douglas-fir in the Pacific Northwest. Phytopathology 66: 710-714.

54. Rattink, H. 1981. Characteristics and pathogenicity of six Phytophthora isolates from pot plants. Neth. J. Pl. Pathol. 87: 83-90.

55. Ribeiro, O.K. 1978. A Sourcebook of the Genus Phytophthora. J. Cramer, Vadiu, FL. 417 pp.

56. Rowe, R.C., and Schmitthener, A.F. 1977. Potato pink rot caused by Phytophthora erythroseptica and P. cryptogea. Plant Dis. Rep. 61: 807-810.

57. Satour, M.M., and El-Shinnawy, S.A. 1972. A new root and crown rot of cucurbits caused by Phytophthora cryptogea. Egypt J. Phytopathol. 5: 65-71.

58. Savage, E.J., Clayton, C.W., Hunter, J.H., Brenneman, J.A., Laviola, C., and Gallegly, M.E. 1968. Homothallism, heterothallism, and interspecific hybridization of the genus Phytophthora. Phytopathology 58: 1004-1021.

59. Schneider, C.L., and Zimmer, D.E. 1965. Pathogenicity and growth rate of Phytophthora drechsleri isolates from safflower and sugarbeet. Plant Dis. Rep. 49: 293-296.

60. Schwinn, F.J. 1959. Untersuchungen zur Systematik der Gattung Phytophthora de Bary. Arch. Mikrobiol. 33: 223-252.

61. Shepherd, C.J. 1978. Mating behavior of Australian isolates of Phytophthora species. I. Inter- and intraspecific mating. Aust. J. Bot. 26: 123-138.

62. Shepherd, C.J., and Pratt, B.H. 1973. Separation of two ecotypes of Phytophthora drechsleri Tucker occurring in Australian native forests. Aust. J. Biol. Sci. 26: 1095-1107.

63. Stamps, J. 1953. Oospore production in paired cultures of Phytophthora species. Trans. Br. Mycol. Soc. 36: 255-259.

64. Stamps, J. 1970. Phytophthora cryptogea. Commonw. Mycol. Inst. Descriptions of pathogenic fungi and bacteria No. 592. 2 pp.

65. Tompkins, C.M., Richards, B.L., Tucker, C.M., and Gardner, M.W. 1936. Phytophthora rot of sugar beet. J. Agric. Res. 52: 205-216.
66. Tompkins, C.M., and Tucker, C.M. 1937. Root rot of China-aster, annual stock, and Transvaal daisy caused by Phytophthora cryptogea. J. Agric. Res. 55: 563-574.
67. Tompkins, C.M., and Tucker, C.M. 1941. Buckeye rot of tomato in California. J. Agric. Res. 62: 467-474.
68. Tucker, C.M. 1931. Taxonomy of the genus Phytophthora Mo. Agric. Exp. Stn. Res. Bull. 208 pp.
69. Tuset Barrachina, J.J. 1977. Contribution al conocimiento del genero Phytophthora de Bary en España. An. INIA/Ser. Prot. Veg. 7: 11-106.
70. Wager, V.A. 1940. Descriptions of the South African Pythiaceae, with records of their occurrence. Bothalia 4: 3-35.
71. Waterhouse, G.M. 1963. Key to the species of Phytophthora de Bary. Commonw. Mycol. Pap. 92. 22 pp.
72. Waterhouse, G.M., and Blackwell, E. 1954. Key to the species of Phytophthora recorded in the British Isles. Commonw. Mycol. Inst., Mycol. Pap. 57. 9 pp.
73. Wilcox, W.F., and Mircetich, S.M. 1985. Pathogenicity and relative virulence of seven Phytophthora spp. on Mahaleb and Mazzard cherry. Phytopathology 75: 221-226.

MYCOTAXON

Vol. XXVII, pp. 321-323 October-December 1986

TREMELLOSTEREUM (TREMELLACEAE) NOV. GEN.

by

L. RYVARDEN

Dep. of Biology, Div. of Botany, Univ. of Oslo, P.O.Box
1045 Blindern, N-0316 Oslo 3, Norway.

SUMMARY

Tremellostereum nov. gen. is described with T. dichroum (Lloyd) Ryv. as type species. It is characterized by a stereoid fruitbody, covered by a cottony tomentum and has cruciate basidia with 2 sterigmata.

In 1922 Lloyd described Stereum dichroum based on a collection by Brace from The Bahamas. He suggested it could be a degenerate form of Gloeoporus dichrous (Fr.) Bres. although he stated that pores were completely absent. He observed neither spores nor basidia. During an examination of Lloyds species described as Stereum, I discovered that S. dichroum has cruciate basidia with two large sterigmata. Thus, it clearly belongs in the Tremellaceae. A search in the literature (Lowy 1971 and McNabb 1973) revealed that there was no suitable genus to accomodate a species with such set of characters.

Tremellostereum (Tremellaceae) nova. gen.
Fructificatio annua, pileata, pileus albus ad ochraceus, gossypinus, hymenium laevis, gelatinosus, roseus, systema hypharum monomiticum, hyphae generatoriae afibulatae, basidia longitudinalia septata, ovoidea cum 2 sterigmatibus grande, sporae ellipsoideae, hyalinae, tenuitunicatae, non-amyloideae.
Type species: Tremellostereum dichroum (Lloyd) Ryv.

Fruitbody annual, pileate, sessile and dimidiate, soft when fresh, light of weight and brittle when dry, pileus white to ochraceous, cottony, spongy to fibrillose, hymenium smooth, dense and cartilaginous when dry, probably gelatinous and pink to pale red when fresh, pale reddish brown when dry, hyphal system monomitic, generative hyphae without clamps, basidia longitudinally septate with two large sterigmata, spores ellipsoid, smooth, hyaline, thinwalled and non-amyloid.

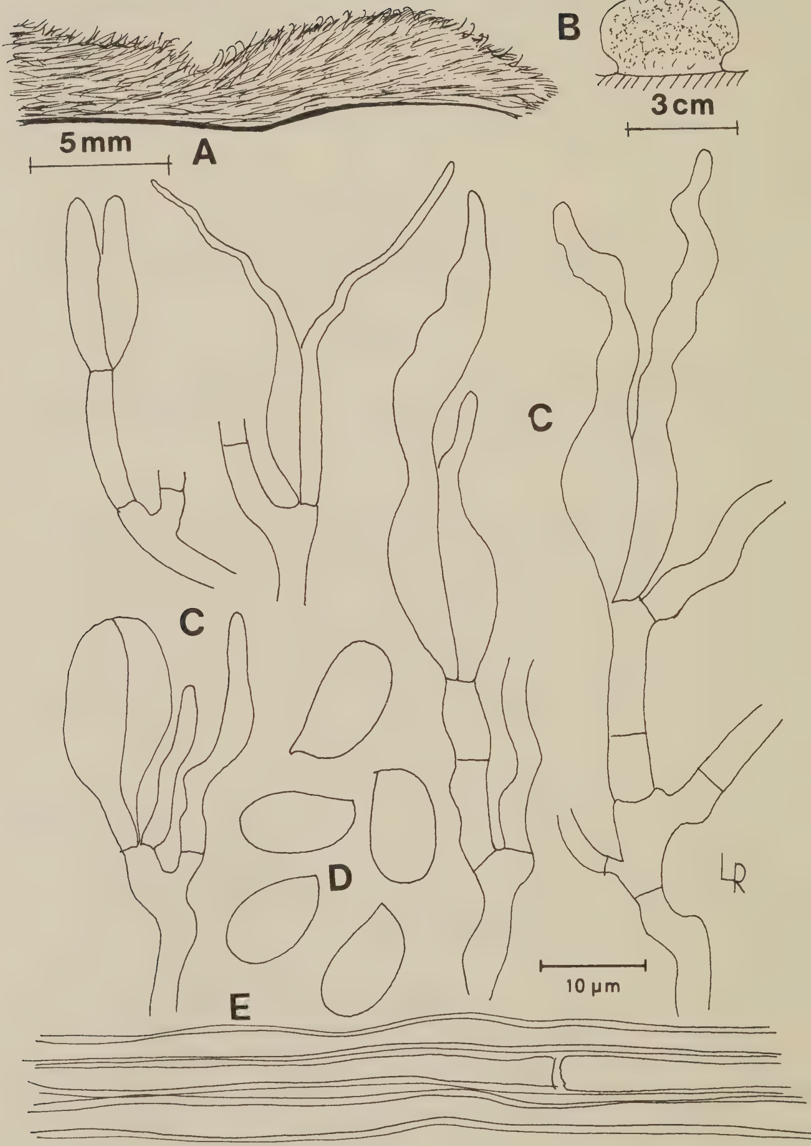

B
3 cm
5 mm
A
C
C
D
10 µm
E
LR

Fig. 1. Tremellostereum dichroum A) section through fruitbody, B) fruitbody seen from above, C) basidia, D) spores, E) hyphae from the tomentum. From the holotype.

Tremellostereum dichroum (Lloyd) Ryv. comb. nov.
Basionym: Stereum dichroum Lloyd, Lloyd mycol. Writ. 7:1158, 1922.

Fruitbody annual, pileate, up to 5 cm long and 3 cm wide, sessile and slightly dimidiate, probably flexible when fresh, light of weight and brittle when dry, pileus white to sand-coloured, cottony to fibrillose and spongy, easily compressed, tomentum up to 4 mm deep, azonate to slightly zonate, margin sharp, hymenium smooth, probably pink to pale red and gelatinous when fresh, pale brown and cartilaginous when dry, strongly contrasting the light-coloured and cottony context.

Hyphal system monomitic, generative hyphae with simple septa in the hymenium sinuous, interwoven, richly branched, hyaline and thinwalled, 2-6 µm wide, in the context and tomentum parallel, slightly thickwalled, straight and with scattered septa.

Metabasidia ovoid, scattered in the hymenium, 20-30 x 8-10 µm, hyaline or partly filled with oily inclusions, longitudinally septate and with two large sterigmata, 12-32 x 3-6 µm, cystidia not seen, spores ellipsoid to subcylindrical with one straight side, hyaline, thinwalled and non-amyloid, 10-12 x 6-7 µm, spore-repetetion not observed.

Only the type is known: Bahamas, Leg. L.J.K. Brace, Lloyd herb. no 8070 (BPI), on dead wood, causing a white rot judged from the attached wood.

The new genus is characterized by its stereoid habit, with a light, spongy and white context and microscopically by its two-sterigmate basidia. Microscopically the closest relative seems to be Tremellodendron, which, however, has branched, erect Clavaria-like fruitbodies and basidia with 4 sterigmata. Microscopically the new genus and Tremellodendron share the same type of simple septate hyphae and ellipsoid, hyaline spores of approximately the same size.

Acknowledgements
Dr. B. Lowy, Lousiana State University, has critically read the manuscript and suggested improvements for which I am very grateful.

References

Lloyd, C.G. 1922: Mycological Notes no 67. Lloyd Mycol. Writ. 7:1137-1168. - Lowy, B. 1971: Tremellales, Flora Neotropica Monograph no 6. New York. - McNabb, R.F.R. 1973: Phragmobasidiomycetidae: Tremellales, Auriculariales, Septobasidiales, p. 303-316 in Ainsworth, G.C., Sparrow, F.K. & Sussman, A.S. (eds.) The Fungi. Vol. IVB. London.

MYCOTAXON

Vol. XXVII, pp. 325-345 October-December 1986

BASIDIOMYCETES THAT DECAY GAMBEL OAK IN SOUTHWESTERN COLORADO: III

J. Page Lindsey

Department of Biology
Fort Lewis College, Durango, Colorado 81301

SUMMARY

Sixteen additional Basidiomycetes that decay **Quercus gambelii** Nutt. in southwestern Colorado are illustrated and described. Two species are described as new: **Hyphoderma anasaziense** and **Platygloea laplata**. A comprehensive key includes all species described in this series of papers.

In two previous papers (Lindsey, 1985; Lindsey 1986) fifty wood-rotting Basidiomycetes were described as decay agents of **Quercus gambelii** Nutt., Gambel oak, in southwestern Colorado. This paper continues and concludes this series with descriptions and illustrations of an additional sixteen Basidiomycetes. Microscopic techniques are described in the initial paper of the series (Lindsey, 1985). Numerical color names are from Munsell's Book of Color (Munsell, 1976); descriptive color names are the author's.

Annotated list of Additional Species that Decay Gambel Oak

ARMILLARIA MELLEA (Vahl:Fr.) Quél., Champ. Jura et Vosges, p. 75. 1872.
Basidiocarps annual, centrally stipitate, single to caespitose around stumps and living trees; pileus up to 15 cm diam, honey colored to golden brown (7.5YR 3/6 to 7.5YR 5/6), covered with fine pointed scales, these often washing off after rains; pileus margin inrolled at first, expanding to plane, slightly striate; lamellae adnate to decurrent, cream colored to light brown; stipe up to 15 cm long and 2.5 cm diam, often with a slightly bulbous base, light brown; annulus superior, whitish. **Hyphal system** monomitic; subhymenial hyphae thin-walled, nodose-septate, the clamps often distorted or difficult to see, 2.5-4 µm diam; tramal hyphae thin-walled, nodose-septate but the clamps often so skewed as to appear simple-septate, up to 8 µm diam. **Cystidia** none. Sterile, hyphoid, simple-septate hymenial elements present in the hymenium, projecting or not, 60-70 x 4-7.5 µm. **Basidia** clavate, 4-sterigmate, becoming very thick-walled and vacuolate at maturity, with a basal clamp, 36-50 x 7.5-9 µm. **Basidiospores** ellipsoid, hyaline, smooth, negative in Melzer's reagent, with a single large guttule, (6-)8-11 x 4.5-6.5 µm. **Comments** - The specimen illustrated had a number of spore forms present which showed various degrees of distortion. **Voucher specimen** - JPL 1224.

CERACEOMYCES SERPENS (Fr.) Ginns, Can. J. Bot. 54:147. 1976.
Basidiocarps effused, shallow-merulioid to reticulate-poroid, remaining so upon drying, hymenium separable, yellowish (2.5Y 8/4) to pinkish

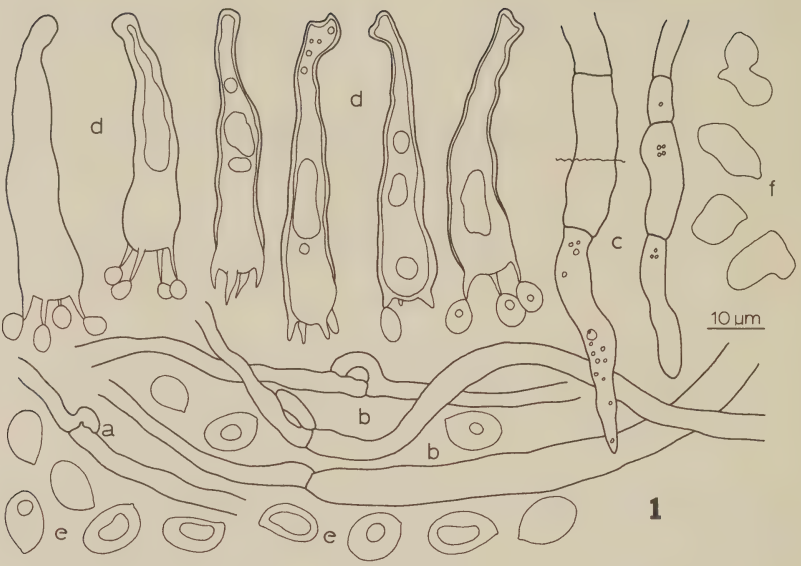


Fig. 1. **Armillaria mellea** (JPL 1224). a) subhymenial hyphae; b) tramal hyphae; c) sterile hymenial elements; d) basidia, most with thickened walls and large vacuoles; e) basidiospores; f) distorted basidiospores.

buff (2.5YR 8/2 to 5YR 8/4); margin smooth, white, broad, fimbriate, weakly rhizomorphic. **Hyphal system** monomitic; subicular hyphae thin-walled, nodose-septate, occasionally branched, 2-6 µm diam. **Sterile hymenial elements** lacking. **Basidia** cylindric-clavate, 4-sterigmate, with a basal clamp, 28-32 x 5.5-7 µm. **Basidiospores** hyaline, smooth, short-cylindric, negative in Melzer's reagent, 4-5 x 2-2.5µm. **Voucher specimen** - JPL 1309.

CERATOBASIDIUM CORNIGERUM (Bourd.) Rogers, Univ. Iowa Studies 17:5. 1935.
Basidiocarps very thin, shiny gray, adherent, a smooth film on the substratum; margin indistinct, abrupt. **Hyphal system** monomitic; subicular hyphae thin- to slightly thick-walled, simple-septate, often collapsing in the subhymenium and difficult to make out, 5-5.5 µm diam. **Sterile hymenial elements** lacking. **Basidia** subglobose to short-clavate, with four broad sterigmata, simple-septate at the base, 13-15 x 6.5-8 µm. **Basidiospores** hyaline, smooth, ellipsoid, negative in Melzer's reagent, strongly cyanophilous, a very few germinating by repetition, 6.5-8 x 4-5 µm. **Comments** - This collection was made on charred oak wood. Only immature basidia with short sterigmata were observed. **Voucher specimen** - JPL 1077.

GLOEOPHYLLUM SEPIARIUM (Wulf.:Fr.) Karst., Finl. Hattsv. 2:80. 1879.
Basidiocarps reflexed, sessile, tough-leathery, usually in scattered groups on slash; pileus surface felty to matted-tomentose to strigose

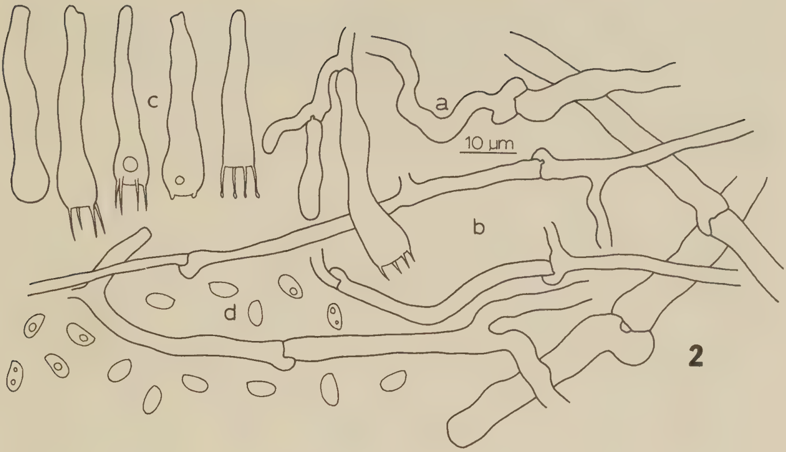


Fig. 2. **Ceraceomyces serpens** (JPL 1309). a) hypha from base of basidial candelabrum; b) subicular hyphae; c) basidia; d) basidiospores.

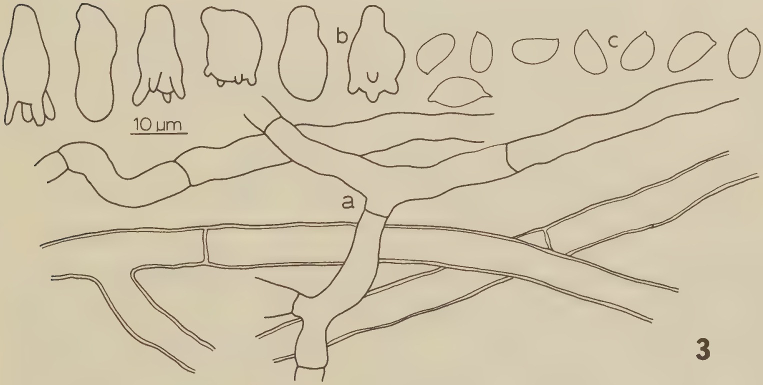


Fig. 3. **Ceratobasidium cornigerum** (JPL 1077). a) subicular hyphae; b) basidia; c) basidiospores.

with concentric zonation in older specimens, the darker areas umber (5YR 2/2), grading to rusty (near 5YR 5/8) and tan (near 10YR 8/6); hymenial surface radially lamellate, grading to daedaloid in older regions, concolorous with the lighter areas of the pileus. **Hyphal system** dimitic; generative hyphae hyaline, thin-walled, nodose-septate, 2-2.5 µm diam; skeletal hyphae brown, aseptate, thick-walled, rarely branched, 2.5-4 µm diam. **Cystidia** hyphoid, not projecting, thin-walled, tapering to an obtuse apex, 34-38 x 4-4.5 µm. **Basidia** slender, cylindric-clavate, 4-sterigmate, varying in length, with a basal clamp, 17-66 x 4.5-6 µm. **Basidiospores** hyaline, smooth, thin-walled, cylindric to slightly curved, negative in Melzer's reagent, 7.5-10 x 2.5-3.5 µm. **Comments** - this collection represents the second brown-rot fungus collected on Gambel oak in this series of papers. **G. sepiarium** is common on conifers but but rare on Gambel oak. The other specimen was **Gloeophyllum trabeum** (Lindsey, 1985). **Voucher specimen** - JPL 1373.

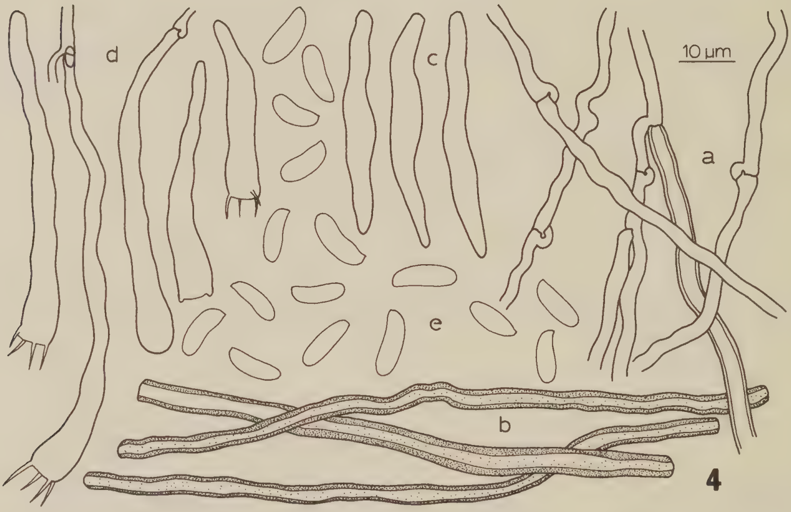


Fig. 4. **Gloeophyllum sepiarium** (JPL 1373). a) nodose-septate generative hyphae; b) skeletal hyphae; c) cystidia; d) basidia; e) basidiospores.

HYPHODERMA ANASAZIENSE Linds., sp. nov.
Basidiocarpi annui, ochracei, effusi-resupinati; hymenii superficies laevis, coacta. Hyphae septatae, fibulatae, 3-5 µm diam; hyphis fasciculis adsunt in subiculo. Cystidia nulla. Basidia tetraspora clavata, fibulata, 28-38 x 4.5-6.5 µm. Basidiosporae hyalinae, tenuitunicatae, laeves, cylindraceae vel ellipsoideae, 5.5-7.5 x 3.0-4.0 µm. **HOLOTYPUS:** J.P. Lindsey 1297, on **Quercus gambelii** Nutt. slash, 8/2/84. East Animas Road, LaPlata County, CO, in herb. National Fungus Collections, Beltsville, MD, U.S.A. (BPI); isotype in herb. ARIZ.

Basidiocarps annual, effused-resupinate, pellicular, felty, smooth, ochre-yellow (near 10YR 8/6 to 2.5Y 9/4); subiculum more loosely arranged, with conspicuous cordons near the substrate, concolorous with the hymenium; margin thinning out to abrupt, fertile. **Hyphal system** monomitic; subicular hyphae hyaline, thin-walled, nodose-septate, 3-5 µm diam; basement **cordons** present in deep subiculum, light golden, the hyphae slightly rough-walled and nodose-septate. **Sterile hymenial**

elements lacking. **Basidia** long-clavate, 4-sterigmate, with a basal clamp, 28-38 x 4.5-6.5 µm. **Basidiospores** hyaline, smooth, negative in Melzer's reagent, cyanophilous, cylindric-ellipsoid, 5.5-7.5 x 3.0-4.0 µm. **Voucher specimen** - JPL 1297 **(HOLOTYPE)**

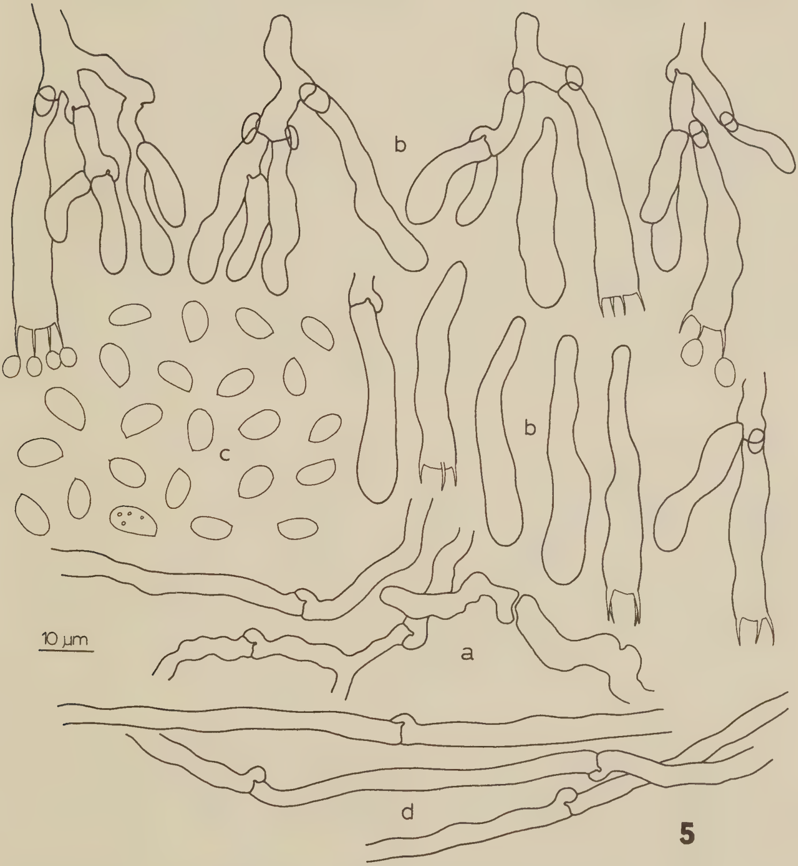


Fig. 5. **Hyphoderma anasaziense** (JPL 1297). a) nodose-septate subicular hyphae; b) basidia; c) basidiospores; d) nodose-septate hyphae from subicular cordons.

HYPHODERMA MEDIOBURIENSE (Burt) Donk, Fungus 27:15. 1957. **Basidiocarps** on well-decayed wood, smooth to slightly tuberculate, effused, buff to pinkish-buff, (10YR 9/2 to 7.5YR 8/2), cracking on

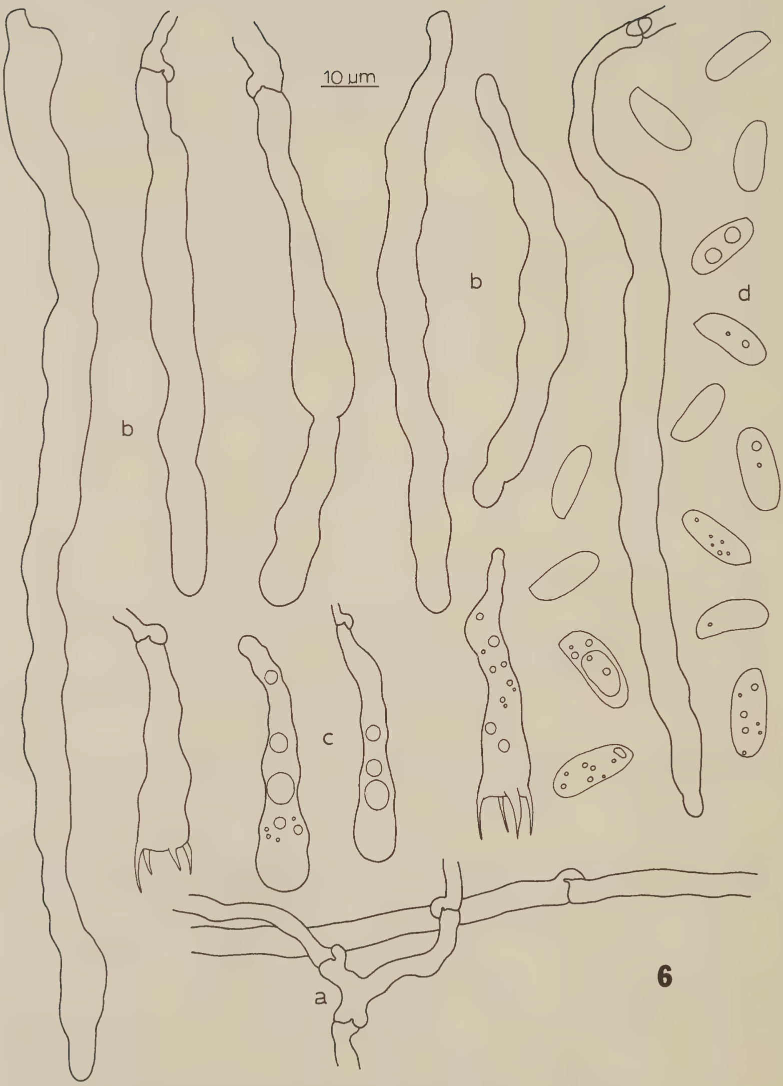


Fig. 6. **Hyphoderma medioburiense** (JPL 1390). a) subicular hyphae; b) leptocystidia; c) basidia, showing oily contents; d) basidiospores, with abundant oily contents.

drying, appearing slightly punctate under higher magnifications (30x) due to resinous accumulations at the cystidial apices; margin abrupt to abruptly thinning out. **Hyphal system** monomitic; subicular hyphae thin-walled, nodose-septate, 3.5-4.5 µm diam. **Leptocystidia** clavate to long-sinuous, some projecting up to 30 µm, others enclosed, thin-walled, with a basal clamp, on the average up to 95 (but some up to 165) x 7-10 µm. **Basidia** clavate, 4-sterigmate, with oily contents, with a basal clamp, 32-40 x 6-9 µm. **Basidiospores** hyaline, smooth, cylindric to allantoid, negative in Melzer's reagent, with abundant oily contents, 11-14 x 4-6 µm. **Voucher specimen** - JPL 1390.

KAVINIA HIMANTIA (Schw.) John Erikss., Sym. Bot. Upsal. XVI:1, p. 160. 1958.

Basidiocarps loosely adherent, resupinate, becoming broadly effused; fertile area byssoid, hydnaceous, the spines up to 0.5 mm long, buff colored (10YR 9/2); margin white, arachnoid to weakly fimbriate, with abundant buff to white rhizomorphs, these penetrating the wood and surrounding humus. **Hyphal system** monomitic; subicular hyphae hyaline, smooth to roughened, some with coarse crystalline encrustation, some becoming slightly thick-walled, some ampullate at the septa, 1.5-3.5µm diam. **Basidia** clavate, 4-sterigmate, some pleurobasidia present, developing along edges of teeth and growing outward, variable in length, with a basal clamp, 30-50 x 5-6 µm. **Basidiospores** slightly olive-green, smooth to bumpy, (the irregular outline seen most readily in Melzer's reagent), negative in Melzer's reagent, narrowly ellipsoid to subfusiform, 8.5-10 x 3-3.5 µm. **Voucher specimen** - JPL 1371.

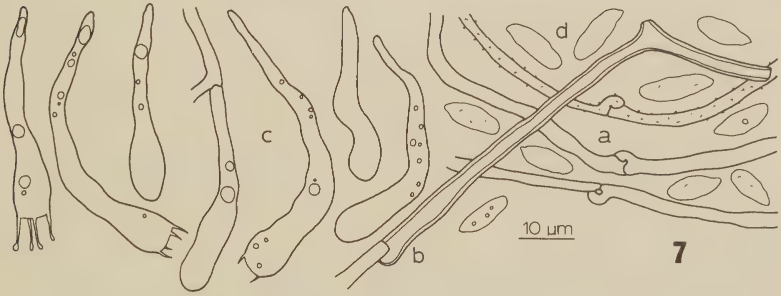


Fig. 7. **Kavinia himantia** (JPL 1371). a) thin-walled subicular hyphae; b) thick-walled subicular hypha, showing ampullate septa; c) basidia of varying lengths; d) smooth to bumpy basidiospores.

PHANEROCHAETE SANGUINEA (Fr.) Pouz., Ceská Mykol. 27:26. 1973.

Basidiocarps adnate, smooth, effused in small patches, yellowish-tan with light orange areas (10YR 9/4 to 7.5YR 8/4), not cracking, orange areas green in KOH; margin strongly fimbriate, white, with occasional pale yellowish rhizomorphs. **Hyphal system** monomitic; subiculum a "textura intricata" (Burdsall, 1985); subicular hyphae thin-walled and richly branched in the subhymenium to thick-walled near the substrate, mostly simple-septate with occasional single and double clamps in the deep subiculum, 3.5-6(-8) µm diam. **Cystidia** abundant, thin-walled, tapering to an acute apex, simple-septate at the base, 46-58.5 x 4-5 µm. **Basidia** slender-clavate, 4-sterigmate, with a simple septum at the base, 33-39 x 3.5-5 µm. **Basidiospores** cylindric-ellipsoid, hyaline, smooth, negative in Melzer's reagent, often with one or two guttules, 4-5.5 x 2-2.5 µm. **Voucher specimen** - JPL 1374.

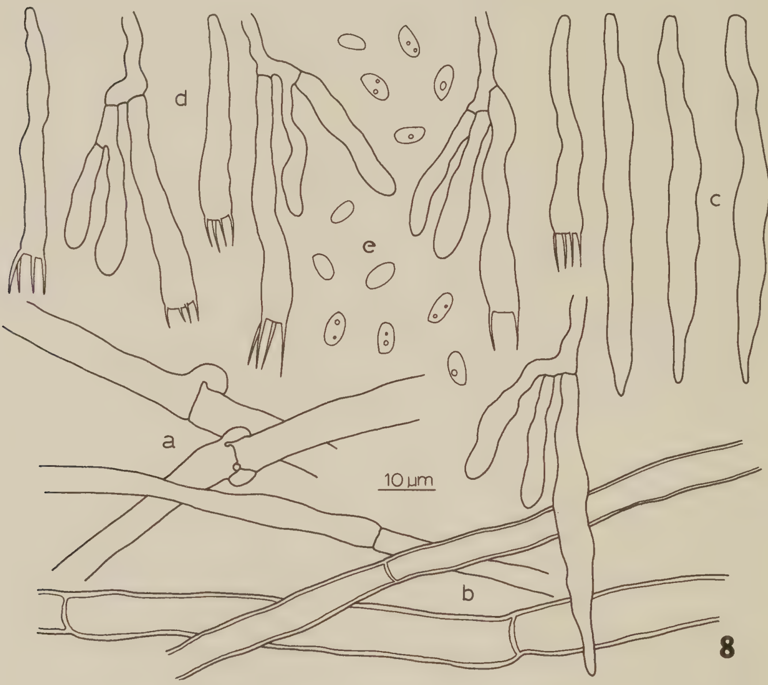


Fig. 8. **Phanerochaete sanguinea** (JPL 1374). a) nodose-septate hyphae from deep subiculum; b) simple-septate subicular hyphae of varying wall thickness; c) leptocystidia; d) basidia; e) basidiospores.

PHANEROCHAETE SORDIDA (Karst.) John Erikss. et Ryv., in John Erikss. et al., Cort. of North Europe, 5:1023. 1978.
Basidiocarps effused on bark, pinkish-buff (10YR 9/4), smooth, compact, membranaceous, cracking on drying to reveal a loose, white subiculum; margin thinning out, white, farinaceous to finely fibrillose under a 10X lens. **Hyphal system** monomitic; subicular hyphae simple-septate, thin-walled in the hymenial area, 2-2.5 µm diam, thick-walled in the deeper areas of the subiculum, 3-7.5 µm diam; no double or multiple clamps seen. **Cystidia** few, cylindric, not encrusted, thin-walled at apex to thick-walled at the base, some with a short lateral projection near the apical end, 52-98 x 4.5-7 µm. **Basidia** clavate, 4-sterigmate,

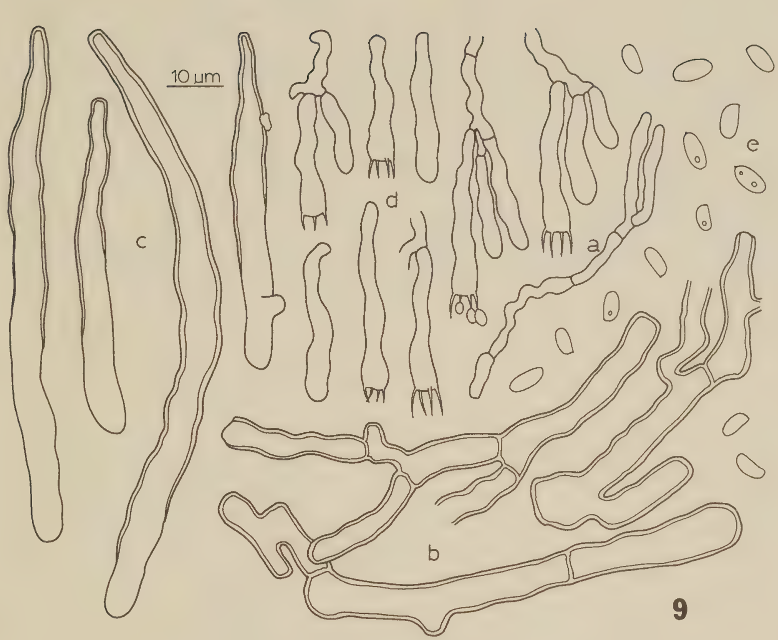
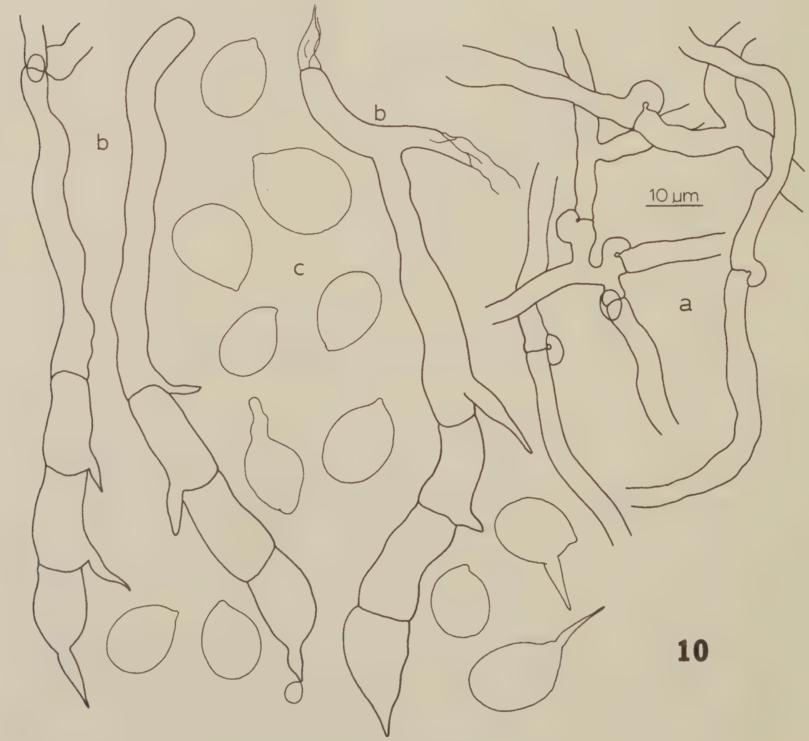


Fig. 9. **Phanerochaete sordida** (JPL 1221). a) thin-walled subcandelabral hypha; b) thick-walled subicular hyphae; c) leptocystidia; d) basidia; e) basidiospores.

with a simple septum at the base, 19-26 x 3.5-4 µm. **Basidiospores** cylindric-ellipsoid, hyaline, smooth, negative in Melzer's reagent, (4-) 4.5-6 x 2-3 µm. **Comments** - Eriksson et al. (1978) and Burdsall (1985) discuss the extreme variability of this species. The sole collection examined in this paper had no encrustation on the cystidia and the cystidia were highly variable in length, with most being short. Only two cystidia were seen that possessed the lateral branches discussed by Eriksson et al. **Voucher specimen** - JPL 1221.

PLATYGLOEA LAPLATA Linds., sp. nov.
Basidiocarpi albidi, farinacei, byssoidei, laeves vel irregulariter verrucati, margo abruptus vel fimbriatus; basidiocarpi parasiticus in basidiocarpo **Peniophora nuda.** Hyphae septatae, fibulatae, 3-4.5 µm diam. Cystidia nulla. Basidia cylindracea, tetracellularia, 90-106 x 8-10 µm; sterigmata vel 14 x 3 µm; basidiosporae hyalinae, laeves, tenuitunicatae, ovoideae, germinans iterum adque iterum, 11.5-17 x 7.5-13 µm. **HOLOTYPUS:** J.P. Lindsey 1279, on **Quercus gambelii** Nutt. slash, 9/29/84. Sheep Springs drainage, LaPlata County, CO, in herb. National Fungus Collections, Beltsville, MD, U.S.A. (BPI); isotype in herb. ARIZ.

Basidiocarps whitish, byssoid, farinaceous, smooth to irregularly warted, growing adjacent to and touching a healthy **Peniophora nuda** basidiocarp; margin abrupt to finely fimbriate **Hyphal system** monomitic; subicular hyphae conspicuously nodose-septate, thin-walled, 3-4.5 µm diam. **Sterile hymenial elements** lacking. **Basidia** long-cylindric, arising directly from thin-walled hyphae, 4-celled, usually with a basal clamp, 90-106 x 8-10 µm; sterigmata up to 14 x 3 µm, arising from the upper end of each cell. **Basidiospores** hyaline, smooth, ovoid, negative in Melzer's reagent, with a blunt apiculus, germinating by repetition laterally or opposite the apiculus, 11.5-15(-17) x 7.5-11 (-13)µm. **Comments** - although this specimen was touching a collection of **Peniophora nuda**, and presumably parasitizing it, it clearly does not fit the existing spore descriptions of **Platygloea peniophorae** Bourd. et Galz. as discussed by Martin (1940). The spores of my collection are much larger than any reports found for **P. peniophorae**. **Voucher specimen** - JPL 1279.



10

Fig. 10. **Platygloea laplata** (JPL 1279). a) nodose-septate subicular hyphae; b) basidia; c) basidiospores, some germinating.

SUBULICYSTIDIUM LONGISPORUM (Pat.) Parm., Consp. Syst. Cort. p. 121. 1968.

Basidiocarps thin, farinaceous, patchy, white to dingy; margin indistinct, concolorous. **Hyphal system** monomitic; subicular hyphae thin- to slightly thick-walled, nodose-septate, often encrusted with plate-like crystals similar to those on the cystidia, 2.5-3 µm diam. **Cystidia** abundant, slender, thick-walled, subulate, heavily encrusted with flattened, evenly spaced crystals except at the extreme apex, with a basal clamp, 45-66 x 2.5-4.5 µm. **Basidia** clavate, 4-sterigmate, some showing a median constriction, with a basal clamp, 11.5-13.5 x 3.5-4 µm. **Basidiospores** hyaline, smooth, acicular, somewhat flexuous, negative in Melzer's reagent, usually with several uniseriate guttules, (12-) 13.5-22 x 1-1.5 µm. **Voucher specimen** - JPL 1222.

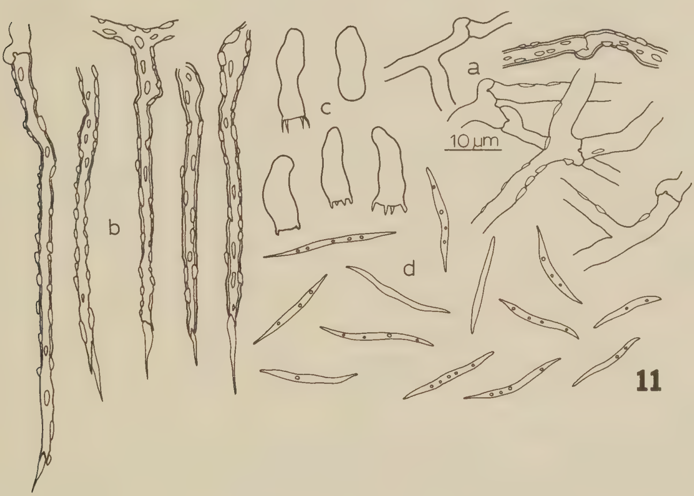


Fig. 11. **Subulicystidium longisporum** (JPL 1222). a) nodose-septate subicular hyphae, some encrusted; b) encrusted cystidia; c) basidia; d) basidiospores.

TOMENTELLA MOLYBDAEA Bourd. et Galz., Bull. Soc. Myc. France 40:142. 1924.

Basidiocarps effused-resupinate, granulose, pinkish-buff (near 10R 7/2); margin thinning out, grayish. **Hyphal system** monomitic; subhymenial hyphae thin-walled, nodose-septate, hyaline, turning light bluish-black in KOH; subicular hyphae hyaline, thin- to slightly thick-walled, nodose-septate, 3-5 µm diam; cordons lacking. **Sterile hymenial elements** lacking. **Basidia** clavate, 4-sterigmate, with granular contents staining bluish-black in KOH, with a basal clamp, 38.5-57 x 6.5-9 µm. **Basidiospores** light brown, echinulate, negative in Melzer's reagent, globose to irregularly globose to lobed, 5.5-7 x 5-5.5 µm. **Voucher specimen** - JPL 1375.

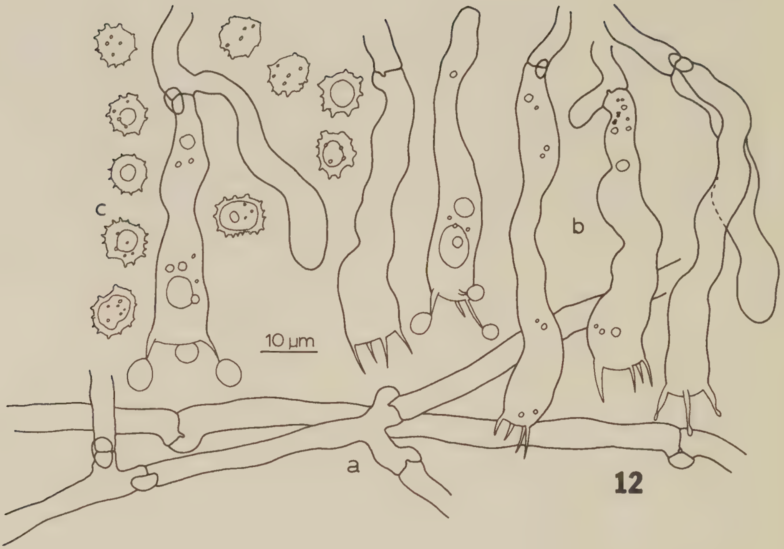


Fig. 12. **Tomentella molybdaea** (JPL 1375). a) subicular hyphae; b) basidia; c) basidiospores.

TOMENTELLA SUBTESTACEA Bourd. et Galz., Bull. Soc. Myc. France 40:144. 1924.
Basidiocarps pale buff (7.5YR 7/2), mucedinoid, arachnoid to granulose, effused on well-decayed wood; margin thinning out, grayish white. **Hyphal system** monomitic; subicular hyphae hyaline, slightly thick-walled, abundantly branched and nodose-septate, 3-4 µm diam. **Cystidia** thin-walled, obclavate to capitate, 21.5-58 x 4.5-8 µm, the capitate apices 3.5-5 µm diam, with a basal clamp, some with one or two clamp connections along their length. **Basidia** long-clavate to cylindric, 4-sterigmate, some with intercalary septa, with a basal clamp, 38.5-56 x 7.5-10 µm. **Basidiospores** dull brown, echinulate, globose to lobed, negative in Melzer's reagent, 6-7 x 4.5-6 µm. **Voucher specimen** - JPL 1389.

TRECHISPORA FARINACEA (Pers.:Fr.) Liberta, Taxon 15:318. 1966.
Basidiocarps effused in small patches, farinaceous to grandinioid, white to grayish-yellow (5Y 8.5/1 to 7.5Y 8/2); margin white, arachnoid, weakly rhizomorphic. **Hyphal system** monomitic; subicular hyphae thin-walled, nodose-septate, some ampullate at the septa, 2-5.5 µm diam. **Sterile hymenial elements** lacking. **Basidia** short-cylindric to clavate, urniform at first, 4-sterigmate, with a basal clamp, 10-13.5 x 4-5 µm. **Basidiospores** hyaline, finely echinulate, ovoid, negative in Melzer's reagent, 3-4 x 2-3 µm. **Voucher specimen** - JPL 1367.

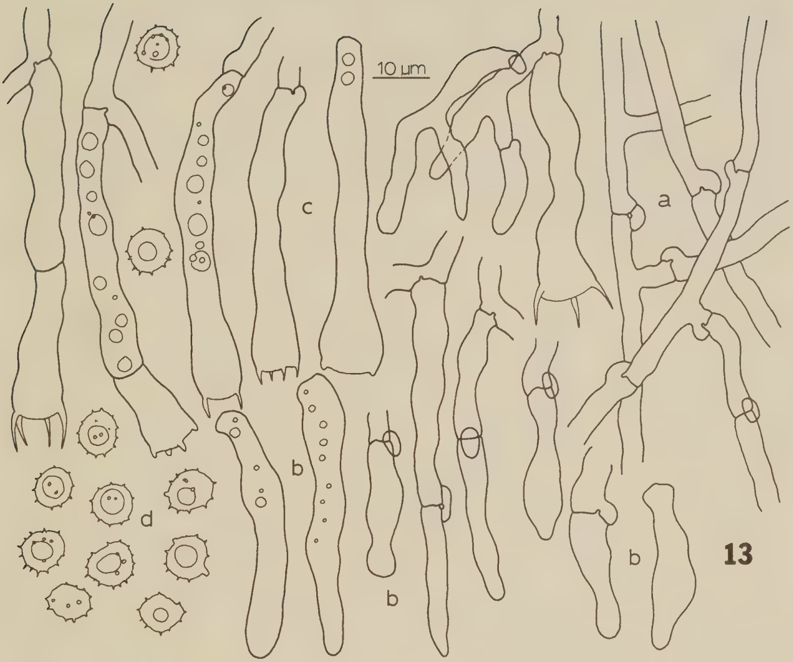


Fig. 13. **Tomentella subtestacea** (JPL 1389). a) subicular hyphae; b) cystidia; c) basidia; d) basidiospores.

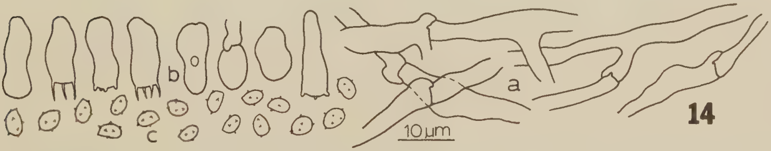


Fig. 14. **Trechispora farinacea** (JPL 1367). a) nodose-septate subicular hyphae with ampullate septa; b) basidia; c) basidiospores.

TRICHOLOMOPSIS PLATYPHYLLA (Fr.) Sing., Schweiz. Zeitschr. Pilzk. 17:56. 1939.

Basidiocarps centrally stipitate, single to scattered on large slash; pileus 3.5-7 cm diam, flat to slightly depressed, shiny gray-brown (near 10YR 7/4), fibrillose; context thin, white; lamellae white to cream, adnate to adnexed, distant; stipe 0.5-1 cm diam, equal or slightly enlarging at base, smooth, twisted, showing spiral striations; annulus lacking. **Hyphal system** monomitic; tramal hyphae of two types: one type thin-walled, nodose-septate, the clamps often distorted, 2.5-8.5 µm diam; the second type inflated, slightly thick-walled, aseptate, tapering to a blunt apex, up to 22 µm diam. **Pleurocystidia** hyphoid to clavate, not projecting, thin-walled, with a basal clamp, 40-45 x 6 µm; **Cheilocystidia** thinner, similar. **Basidia** clavate, with a narrowly tapered base subtended by a clamp, with abundant oily contents, 39-41 x 8-9 µm. **Basidiospores** hyaline, smooth, ellipsoid to ovoid, negative in Melzer's reagent, 8.5-10 x 5.5-7.5 µm. **Voucher specimen** - JPL 1082.

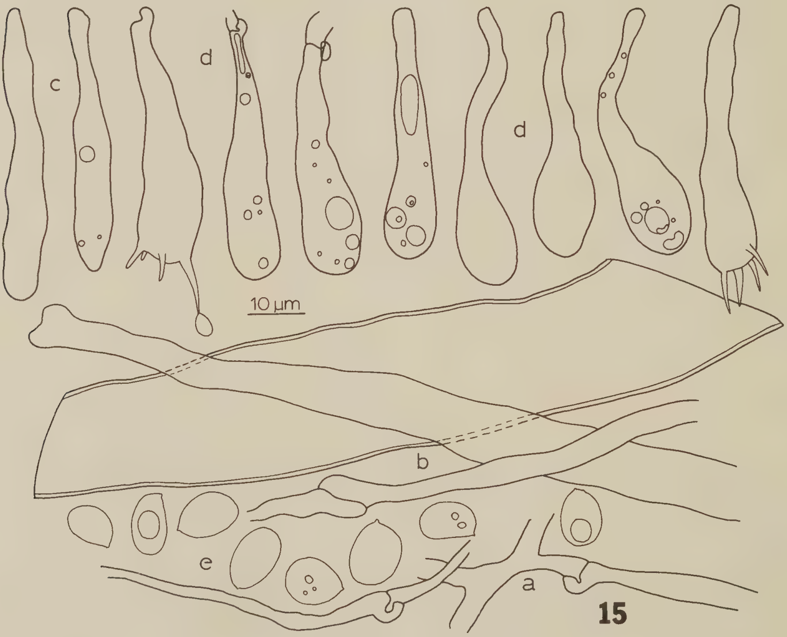


Fig. 15. **Tricholomopsis platyphylla** (JPL 1082). a) subhymenial hyphae; b) tramal hyphae of various diameters, some apparently aseptate; c) pleurocystidia; d) basidia; e) basidiospores.

PHAEOMARASMIUS ERINACEUS (Fr.) Kühner. Encyc. Myc. 7:33. 1935. **Basidiocarps** reviving when moistened, up to 1 cm broad and 1.5 cm high, on attached dead branches or slash; pileus depressed, roughly scaly-hairy, near 2.5YR 3/4; stipe central, concolorous with pileus, equal, wooly; annulus none; lamellae white to pinkish. **Hyphal system monomitic**; tramal hyphae hyaline, thin-walled, with clamps, 3-4 µm diam;

hyphae comprising pileus tomentum pseudoamyloid in Melzer's reagent, corrugated, pigmented, thick-walled, with clamps, 4-8 µm diam. **Cystidia** of two types: pleurocystidia fusoid, 30-42 x 7-10 µm, sometimes absent; cheilocystidia fusoid, 20-35 x 4-9 µm. **Basidia** clavate, 4-sterigmate, with a basal clamp, 35-43 x 7-8 µm. **Basidiospores** ovoid to short-ellipsoid, lightly pigmented, straw-colored in KOH, smooth, negative in Melzer's reagent, 8-10 x 4.5-6 µm. **Comments** - Smith and Hesler (1968) call this species **Pholiota erinacea** (Fr.) Rea. The light pinkish spore print, however, led Singer (1963) to refer it to **Phaeomarasmius**. Personal communications with Dr. Roy Halling and Dr. David Largent suggest that it is best left in this genus. This fungus is not uncommon on slash and dead attached limbs. It causes a stringy white rot. **Voucher specimens** - JPL 1151; JPL 1190; JPL 1368.

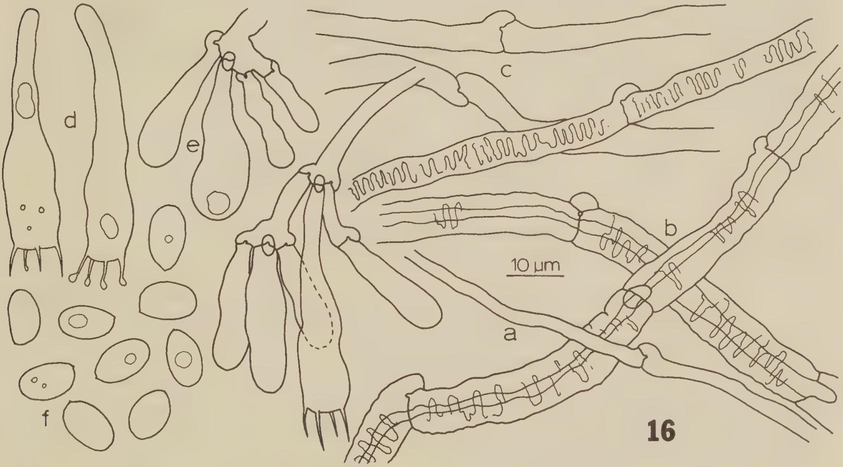


Fig. 16. **Phaeomarasmius erinaceus** (JPL 1151). a) subhymenial hypha; b) encrusted hyphae from pileus tomentum; c) hypha from trama of pileus; d) basidia; e) basidial candelabrum; f) basidiospores.

CONCLUSIONS

Sixty-six species of wood-inhabiting basidiomycetes have been reported on Gambel oak from southwestern Colorado in a series of three papers. These fungi play differing roles in the ecology of the host tree. Most are active decomposers of slash on the ground. The most conspicuous of these are **Polyporus arcularius** and **Pycnoporus cinnabarinus**. Some fungi are most frequently associated with dead branches on living trees. **Exidia glandulosa** and **Hyphodontia crustosa** are predominant in this category. Finally, **Inonotus andersonii** is a parasite of living trees; it kills out tops or sometimes entire trees. It is extremely common in the clonal scrub stands of oak in this area.

Most of the fungi identified on Gambel oak are white-rot fungi. Brown-rot fungi are common on associated trees, such as **Pinus ponderosa**

Laws. and **Populus tremuloides** Michx. It seems likely that brown-rot fungi do not favor the oak substratum. This is of interest in relation to the work of Jurgensen et al. (1977) which points out the importance of brown-rot fungi in soil building, mycorrhizal formation, and water retention. Many fungi not reported in this series of papers ultimately will be (and have been) found on this substratum, especially in areas such as Utah, Arizona, and New Mexico, where environmental conditions favor different kinds of fungi. However, the sixty-six species reported seem to represent a fair cross-section of the mycota of this area. These wood-rotting fungi are important in returning organic materials to the soil. Many oak brush stands are on extremely steep slopes, where they stabilize the soil against mud slides and less severe forms of erosion. The white rot fungi predominating on oak contribute, however slowly, to the soil building process. Because of the continued interest in eradication of Gambel oak through burning and herbicide treatment for improvement of wildlife grazing and cattle pasture, and because of the increased interest in this species for firewood, it is critical that we know more about the ecology of the oak woodlands in this area. Further studies on the impact of long-term oak brush eradication should be pursued.

KEY TO SPECIES OF WOOD-ROTTING BASIDIOMYCETES THAT DECAY GAMBEL OAK

1a. Basidia of the holobasidium type 4
1b. Basidia of the heterobasidium type.............................. 2

2a. Basidia bifurcate .... **Dacrymyces minor**
2b. Basidia cruciately septate or transversely septate 3

3a. Basidia cruciately septate; basidiocarp gelatinous, black to brown .... **Exidia glandulosa**
3b. Basidia transversely septate; basidiocarp dry, white .... **Platygloea laplata**

4a. Basidiocarp agaricoid, fleshy, with hymenium borne on radiating lamellae 5
4b. Basidiocarp poroid, toothed, smooth, or merulioid; if fleshy, not with hymenium borne on radiating lamellae; if lamellate, then tough and fibrous......................11

5a. Basidiocarps eccentrically stipitate to sessile 6
5b. Basidiocarps centrally stipitate 8

6a. Basidiocarps minute (1-3 mm diam), bluish-black; basidiospores globose .... **Resupinatus applicatus**
6b. Basidiocarps larger, buff-colored; basidiospores ovoid to short-cylindric 7

7a. Basidiospores minutely echinulate, amyloid in Melzer's reagent .... **Lentinellus cochleatus**
7b. Basidiospores smooth, negative in Melzer's reagent ... **Panus rudis**

8a. Spore print pure white, basidiospores smooth 10
8b. Spore print pinkish, clay-colored or brown, spores smooth or tuberculate... 9

9a. Basidiocarps orange to rust-colored; basidiospores ellipsoid to broadly fusiform, verrucose, 6.5-9 x 4.5-6 µm .... **Gymnopilus sapineus**
9b. Basidiocarps small, brown, hairy; basidiospores ovoid to short-ellipsoid, 8-10 x 4.5-6 µm .... **Phaeomarasmius erinaceus**

10a. Annulus present; young pileus surface with fine, pointed scales .... **Armillaria mellea**
10b. Annulus lacking; pileus surface glabrous to appressed fibrillose .... **Tricholomopsis platyphylla**

11a. Basidiocarp tough, not fleshy; hymenophore poroid to daedaloid or radially lamellate 12
11b. Basidiocarp not fleshy; hymenophore hydnoid, merulioid, smooth, or irregular 26

12a. Hyphal system monomitic 13
12b. Hyphal system di- or trimitic 18

13a. Generative hyphae nodose-septate 14
13b. Generative hyphae simple-septate 15

14a. Basidiocarps effused-resupinate, cream-colored .... **Ceriporiopsis mucida**
14b. Basidiocarps resupinate to pileate, reddish-brown with a golden pore surface, turning cherry red in KOH...............**Hapalopilus nidulans**

15a. Basidiocarps resupinate, whitish to pinkish-tan 16
15b. Basidiocarps hoof-shaped, golden-brown, with a granular core.............................. **Inonotus dryophilus**

16a. Basidiospores reniform to broadly allantoid .... **Ceriporia reticulata**
16b. Basidiospores cylindric-ellipsoid 17

17a. Basidiospores 4-4.5 x 2-2.5 µm .... **Ceriporia tarda**
17b. Basidiospores 4-5 x 3-3.5 µm .... **Ceriporia excelsa**

18a. Hyphal system trimitic 19
18b. Hyphal system dimitic 21

19a. Basidiocarps whitish 20
19b. Basidiocarps bright orange .... **Pycnoporus cinnabarinus**

20a. Basidiospores hyaline, thick-walled, dextrinoid in Melzer's reagent, 5.5-8.5 x 4.5 µm .... **Perenniporia medulla-panis**
20b. Basidiospores hyaline, allantoid, negative in Melzer's reagent 3.5-5 x 0.5-1 µm .... **Incrustoporia nivea**

21a. Basidiocarps brownish-grey to blackish 22
21b. Basidiocarps tan to bright-colored 25

22a. Hymenophore ranging from poroid to daedaloid to lamellate 23
22b. Hymenophore distinctly poroid 24

23a. Basidiospores 7.5-8.5 x 3.5-4.5 µm; basidia up to 26 µm long .... **Gloeophyllum trabeum**
23b. Basidiospores 7.5-10 x 2.5-3.5 µm; basidia up to 66 µm long................................ **Gloeophyllum sepiarium**

24a. Basidiospores pigmented; basidiocarps fruiting between bark and wood .... **Inonotus andersonii**
24b. Basidiospores hyaline; basidiocarps fruiting on dead branches .... **Phellinus ferruginosus**

25a. Basidiocarps tan; centrally stipitate .... **Polyporus arcularius**
25b. Basidiocarps white to bright lemon-yellow; effused-resupinate .... **Perenniporia tenuis**

26a. Basidiocarps with a distinctly loose to densely toothed hymenophore 27
26b. Basidiocarps with hymenophore tuberculate, smooth, merulioid, or otherwise 32

27a. Basidiocarps densely aculeate to hydnaceous 28
27b. Basidiocarps warted to furfuraceous 31

28a. Basidiocarps white to cream colored or buff 29
28b. Basidiocarps vinaceous; margin strongly fimbriate and rhizomorphic .... **Steccherinum fimbriatum**

29a. Lagenocystidia present .... **Hyphodontia arguta**
29b. Lagenocystidia lacking 30

30a. Basidiocarps loosely attached, hydnaceous; margin white, with abundant rhizomorphs .... **Kavinia himantia**
30b. Basidiocarps strongly adherent, aculeate, with fimbriate apices to the aculei .... **Hyphodontia crustosa**

31a. Basidiocarps waxy, irregularly warted to folded to hydnoid .... **Phlebia albida**
31b. Basidiocarps porose-reticulate to furfuraceous, in places with blunt aculei .... **Hyphodontia subalutacea**

32a. Basidiocarps felty to arachnoid to byssoid 33
32b. Basidiocarps pellicular to compact 42

33a. Cystidia present 34
33b. Cystidia and other sterile hymenial elements lacking 36

34a. Cystidia projecting, hyphoid, abundantly clamped, lightly encrusted; basidiopores hyaline, smooth .... **Amphinema byssoides**
34b. Cystidia obclavate to broadly capitate; basidiospores pigmented, rough-walled................................... 35

35a. Basidiocarps pale buff; cystidia obclavate to capitate, the capitate apex up to 5 µm diam .... **Tomentella subtestacea**
35b. Basidiocarps gray-brown; cystidia golden, broadly capitate, the apical cell up to 14 µm diam .... **Tomentella pilosa**

36a. No basidia present in hymenium; thick-walled conidiophores and limoniform conidia present .... **Oidium candicans**
36b. Basidia present in hymenium 37

37a. Basidiocarps dark reddish-brown to rust 38
37b. Basidiocarps buff, white, gray, or yellow 39

38a. Basidiocarps rust-colored; basidiospores lobed or irregular, 7-8 x 5-6 µm .... **Tomentella ferruginea**
38b. Basidiocarps dark reddish-umber; basidiospores globose, aculeate, 7.5-9 µm diam .... **Tomentella ramossissimum**

39a. Basidiocarps with a distinct pinkish-buff tint .... **Tomentella molybdaea**
39b. Basidiocarps whitish, yellowish, to brownish 40

40a. Basidiospores smooth, limoniform, biapiculate .... **Botryobasidium botryosum**
40b. Basidiospores echinulate, ovoid to ellipsoid 41

41a. Basidiocarps whitish, farinaceous to grandinioid; basidiospores 3-4 x 2-3 µm .... **Trechispora farinacea**
41b. Basidiocarps separable, olive to dull yellow, felty, with abundant cordons; basidiospores 4.5-5 x 3-3.5 µm ....**Trechispora vaga**

42a. Sterile hymenial elements (setae, acanthophyses, cystidia, etc.) lacking 43
42b. Sterile hymenial elements present 51

43a. Basidiocarps pellicular, separable, not felty 44
43b. Basidiocarps attached, adherent 46

44a. Basidiospores globose to subglobose ...... **Athelia coprophila**
44b. Basidiospores ellipsoid 45

45a. Basidiospores narrowly ellipsoid to pip-shaped, 5-6 x 2-3 µm .... **Athelia bombycina**
45b. Basidiospores ellipsoid, 3.5-4.5 x 2-2.5 µm .... **Fibulomyces mutabilis**

46a. Basidia short to slender-clavate, 4-sterigmate 47
46b. Basidia utriform, (4-)6-8 sterigmate...**Sistotrema brinkmannii**

47a. Basidiocarps shallow-merulioid, reticulate-poroid or slightly phlebioid (hand lens may be necessary) 48
47b. Basidiocarps smooth to tuberculate 49

48a. Hymenium shallow-merulioid to reticulate-poroid, yellowish to pinkish-buff; weakly rhizomorphic ...... **Ceraceomyces serpens**
48b. Hymenium smooth to slightly phlebioid, cracking along folds upon drying, pinkish-buff to pinkish-gray; rhizomorphs present, penetrating into wood and bark ... **Phlebia lilascens**

49a. Basidiocarp a shiny, thin film on the substrate .... **Ceratobasidium cornigerum**
49b. Basidiocarp thicker, subiculum often visible (with hand lens) through cracks or pock-marks in the hymenium 50

50a. Basidiocarps white to cream or ochraceous, often cracking on drying; margin white, fibrillose, rhizomophic; clamp connections lacking .... **Phanerochaete tuberculata**
50b. Basidiocarps felty-pellicular, yellow-ochraceous; margin thinning out to abrupt; clamp connections present .... **Hyphoderma anasaziense**

51a. Gloeocystidia or pseudocystidia present 52
51b. Gloeocystidia or pseudocystidia absent 55

52a. Acanthohyphidia abundant; basidiospores amyloid in Melzer's reagent .... **Aleurodiscus cerrusatus**
52b. Acanthohyphidia lacking; basidiospores negative in Melzer's reagent 53

53a. Basidiocarps grayish-blue to white .... **Peniophora violaceolivida**
53b. Basidiocarps pinkish-buff to orangish-gray 54

54a. Gloeocystidia 38-75 x 8-13 µm; basidiospores 6.5-8 x 2.5-3 µm .... **Peniophora pseudoversicolor**
54b. Gloeocystidia 42-48 x 8.5-11.5 µm; basidiospores 7.5-8.5 x 3-3.5 µm .... **Peniophora nuda**

55a. Thick-walled pigmented or encrusted sterile hymenial elements present 56
55b. Sterile hymenial elements not thick-walled (except at base) 59

56a. Darkly pigmented, subulate setae present .... **Hymenochaete arida**
56b. Encrusted lamprocystidia present 57

57a. Cystidia amyloid, dissolving in 3% KOH .... **Tubulicrinis calothrix**
57b. Cystidia not amyloid 58

58a. Cystidia subulate, encrusted with flat, evenly-spaced crystals except at extreme apex .... **Subulicystidium longisporum**
58b. Cystidia large, projecting, thick-walled, heavily encrusted at apex and up to 2/3 of their length .... **Phanerochaete velutina**

59a. Basidiocarps dimitic; basidiospores amyloid in Melzer's reagent .... **Stereum hirsutum**
59b. Basidiocarps monomitic; basidiospores negative in Melzer's reagent 60

60a. Basidiocarps yellow to orange 61
60b. Basidiocarps white to pinkish-buff 62

61a. Basidiocarps yellowish-tan with light orange areas, the orange areas turning green in KOH; cystidia thin-walled, 46-58.5 x 4-5 µm; basidiospores 4-5.5 x 2-2.5 µm .... **Phanerochaete sanguinea**
61b. Basidiocarps bright orange-yellow when fresh, fading to a dull yellow upon drying; cystidia thin-walled, 63-78 x 4.5-6.5 µm; basidiospores 4-5 (-6) x 2.5-3 µm .... **Phanerochaete carnosa**

62a. Basidiocarps bright white; capitate, projecting cystidia and embedded stephanocysts present ..... **Hyphoderma praetermissum**
62b. Basidiocarps pinkish-white to buff........................ 63

63a. Leptocystidia thin-walled, long sinuous, some over 130 µm long; basidiospores 11-14 x 4-6 µm .... **Hyphoderma medioburiense**
63b. Leptocystidia thick-walled at base, mostly shorter than 100 µm; basidiospores ranging 4-6 x 2-3 µm 64

64a. Cystidia thin-walled, 55-90 µm x 5-7 µm .... **Phanerochaete arizonica**
64b. Cystidia thin-walled at apex to thick-walled at base, some with short lateral projections near the apical end, 52-98 x 4.5-7 µm .... **Phanerochaete sordida**

ACKNOWLEDGEMENTS

Thanks are gratefully extended to: Mrs. Donna Giersch for typing, proofreading, and helpful suggestions; Dr. Roy Halling and Dr. David Largent, for identification of **Phaeomarasmius erinaceus**; and Dr. R.L. Gilbertson for critical review of the manuscript.

LITERATURE CITED

Burdsall, H.H., Jr. 1985. A contribution to the taxonomy of the genus **Phanerochaete** (Corticiaceae, Aphyllophorales). J. Cramer, New York. 165 p.
Eriksson, John, Kurt Hjortstam, and Leif Ryvarden. 1978. The Corticiaceae of North Europe. Vol. 5. Fungiflora, Oslo.
Jurgensen, M.F., M.J. Larsen, and A.E. Harvey. 1977. Effects of timber harvesting on soil biology. pp. 244-260. In forests for people. A challenge in world affairs. Proc. Soc. Am. Foresters.
Lindsey, J. Page. 1985. Basidiomycetes that decay Gambel oak in southwestern Colorado. Mycotaxon 22:327-362.
Lindsey, J. Page. 1986. Basidiomycetes that decay Gambel oak in southwestern Colorado: II. Mycotaxon 25:67-83.
Martin, G.W. 1940. Some heterobasidiomycetes from eastern Canada. Mycologia 32:683-695.
Munsell Book of Color. 1976. (Ed.) Munsell Color Co., Inc., Baltimore MD.
Smith, Alexander H. and L.R. Hesler. 1968. The North American Species of **Pholiota**. Lubrecht and Cramer, New York. 394 p.
Singer, Rolf. 1963. The Agaricales in Modern Taxonomy, 2nd Ed. **Pholiota**, pp. 550-558. Weinheim.

MYCOTAXON

Vol. XXVII, pp. 347-360 October-December 1986

Lahmia Körber (= Parkerella A. Funk) a misinterpreted genus with isolated position.

Ove Eriksson

Institute of Ecological Botany,
University of Umeå, S-901 87 Umeå, Sweden

ABSTRACT

The only species accepted in the genus **Lahmia** Körber, **L. kunzei** Körber, has been considered a non-lichenized discomycete with lecanoralean ascomata, but is shown here to differ so much from other ascomycetes that it has to be referred to a new family in a new order (Lahmiaceae, Lahmiales). **Parkerella** Funk, originally described as an aberrant genus in Coronophorales, is a synonym.

INTRODUCTION

Some interesting fungi have been described on bark of **Populus** spp. from North America during the two last decades. Rough bark on **P. balsamifera** may be caused by the bitunicate pyrenomycete **Rhytidiella moriformis** Zalasky (1968: 1383, 1975: 780). The cork bark disease on **P. tremuloides** is believed to be caused by another **Rhytidiella** species, **R. baranyayi** Funk & Zalasky (1975: 752). Funk (1976: 868) found that this species is often associated with another fungus, which he described as **Parkerella populi** gen. et sp. nov. in the order Coronophorales.

The first European record of **R. moriformis** was reported on **Populus tremula** from N. Sweden a few years ago (Eriksson 1981: 51). This find initiated a search for aspens with cork bark disease in Sweden. **Rhytidiella baranyayi** was never encountered, but quite recently it suddenly occured to me that **Parkerella populi** may be a fungus that has been known from Europe for more than 120 years, viz. **Lahmia kunzei** Körber. This is a wide-spread and common, but overlooked fungus on **Populus tremula**. It has been treated as a discomycete, but it perfectly matches Funk´s description of the pyrenomycete **Parkerella populi**. A closer examination reveals that its morphology has been misinterpreted and that it is not closely related to any order in current classifications. The present paper gives information about the nomenclature, morphology, systematic position, and biology of this fungus.

MATERIALS AND METHODS

Semithin sections of material embedded in LKB 2218-500 Historesin were cut with glass knives in an LKB Histo-Range Microtome. SEM graphs were made with a JEOL JSM-P15.

RESULTS

Lahmia Körber 1861: 281.
Syn.: **Parkerella** A. Funk (non **Parkerella** Muniers-Chalmas ex L. Morellet & J. Morellet, 1922; fossil alga; see Farr & al. 1979: 1266), Can. J. Bot. 54: 686, 1976.

Lahmia kunzei Körber 1861: 282
Syn.: **Parkerella populi** A. Funk, l.c.
Figs.: 1-3.

Ascomata scattered or occasionally 2 or 3 close together, erumpent, turbinate, when dry with flat or slightly concave upper surface (very young ascomata convex), swelling in water and fertil portion then becoming subglobose and up to ca. 300 x 250 um, stipe up to ca. 300 um high, non-ostiolate, uniloculate, black, upper surface of dry asco-

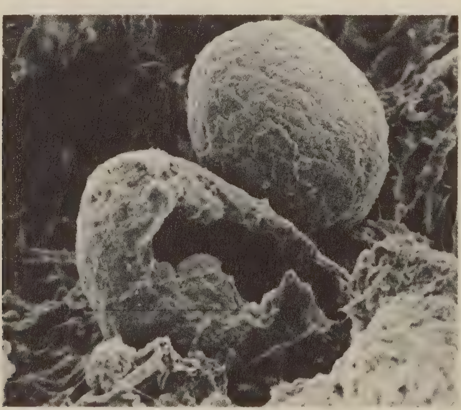


Fig. 1. **Lahmia kunzei**. Two ascomata, one unopened and one opened. Coll.: UME 29061. Magn.: x100.

mata with small fissures in SEM (Fig. 1).

Wall composed of a net-work of hyphae (textura intricata) with thick, scleroplectenchymatous walls, and intercellulars filled with a gelatinous substance, strongly melanized around surface hyphae (Fig. 2B), greyish green under the surface layer and hyaline near the hamathecium.

Mature ascomata opening and exposing the asci by the radial and irregularly splitting and partial disintegration from centrum outwards of the upper part of the wall; empty,

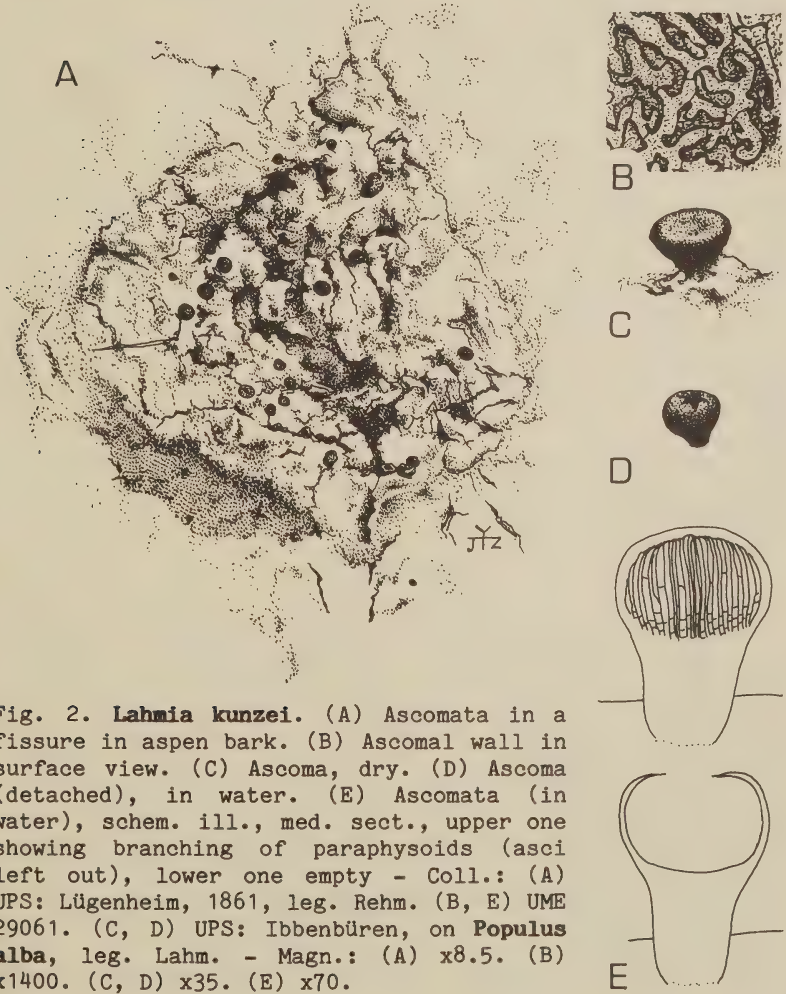


Fig. 2. **Lahmia kunzei.** (A) Ascomata in a fissure in aspen bark. (B) Ascomal wall in surface view. (C) Ascoma, dry. (D) Ascoma (detached), in water. (E) Ascomata (in water), schem. ill., med. sect., upper one showing branching of paraphysoids (asci left out), lower one empty - Coll.: (A) UPS: Lügenheim, 1861, leg. Rehm. (B, E) UME 29061. (C, D) UPS: Ibbenbüren, on **Populus alba,** leg. Lahm. - Magn.: (A) x8.5. (B) x1400. (C, D) x35. (E) x70.

very thin-walled, cup-shaped ascomata (Fig. 1) with whitish wall flaps at the rim, often seen with unopened and opened, mature ascomata.

Hamathecium in young ascomata (before asci are to be seen) consisting of filiform, anastomosing paraphysoids, ca. 1-2 µm diam., directly continuing into the hyphae of the surrounding tissues without any visible change in anatomy. Paraphysoids streching between and above asci during ontogenesis and here with much fewer anastomoses than in basal part of hymenium; uppermost part of hamathecium secondarily producing paraphysis-like filaments with free, slightly swollen tips, ca. 2-3 µm diam. (Fig. 3F), densely agglutinated by a thin covering layer of faintly brownish, amorphous grains; hymenial gel around paraphysoids in mature ascomata inconspicuous (stainable with, e.g. Brilliant Chresyl Blue (BCB) in water mounts).

Asci clavate, very long-stalked, with hoof-like or bifurcated bases, bitunicate, but probably non-fissitunicate, ectotunica thin, endotunica thin in asci with mature spores, thick in broken asci (Fig. 3B), in upper part of immature asci and in mature asci treated with KOH, with a small ocular chamber, but without distinct ring structures, (in mounts stained with BCB, a central cylindrical portion stains less strongly than surrounding parts), 8-spored, maturing almost synchronously, I-, 85-110 x 10-14 µm, easily breaking at the bases and squeezed out in water mounts.

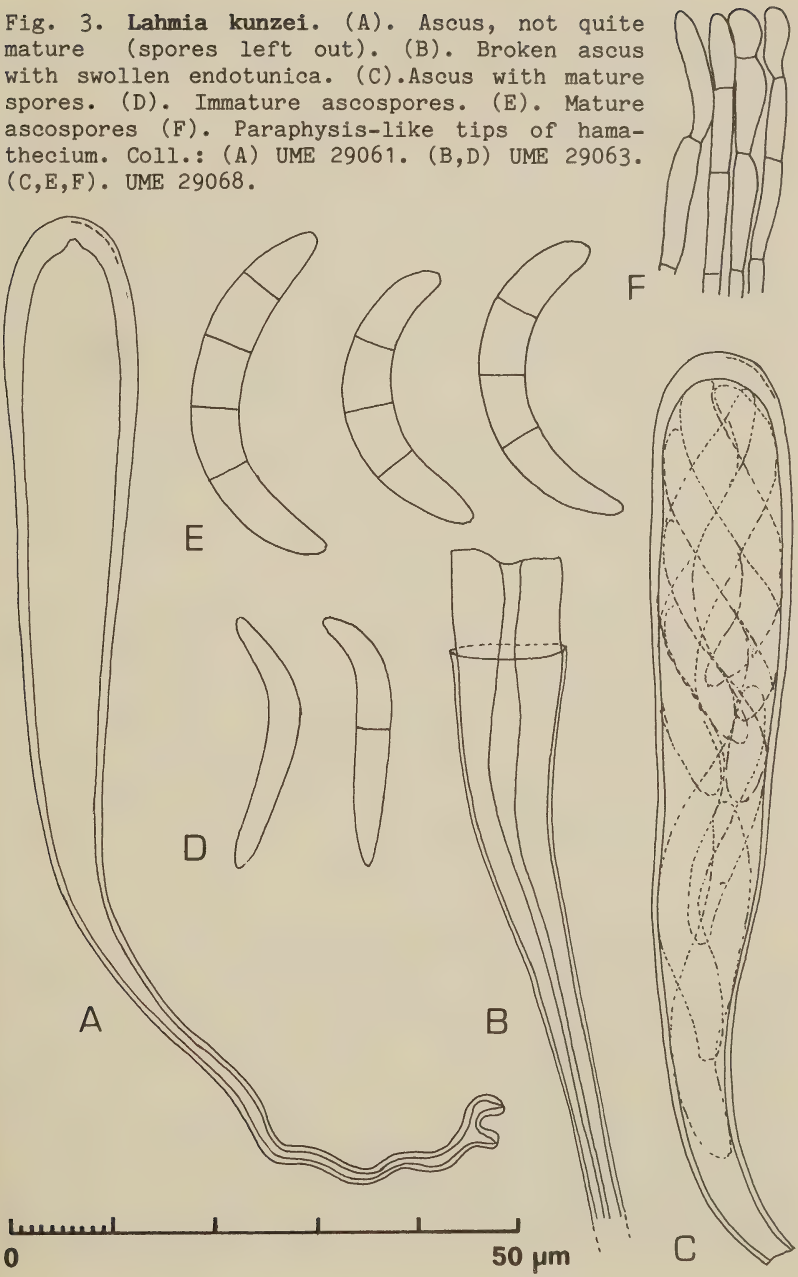
Ascospores hyaline, crescent-shaped, contorted,(1-)3(-4)-septate, 18-37 x 4-5 µm, thin-walled, without distinct perispore (Fig. 3 C,D,E).

DISCUSSION

Morphology

Lahmia kunzei is characterized by erumpent, stalked, truncate, initially closed, hemiangiocarpous ascomata breaking up irregularly by the splitting and partial disintegration of the upper wall at maturity, ascomal wall of textura intricata, hamathecium of paraphysoids with secondary paraphysis-like ends, morphologically bitunicate asci with very long and narrow stalks, easily breaking at the base and becoming loose, and spirally twisted, finally several-septate ascospores. Funk (1976: 868) gave a good description of this species (as **Parkerella populi**), and presented several excellent photographs. The Swedish material agrees well with the protologue of Funk´s new species, and there can be no doubt about their being conspecific. There are a few small differences, however,

Fig. 3. **Lahmia kunzei.** (A). Ascus, not quite mature (spores left out). (B). Broken ascus with swollen endotunica. (C).Ascus with mature spores. (D). Immature ascospores. (E). Mature ascospores (F). Paraphysis-like tips of hamathecium. Coll.: (A) UME 29061. (B,D) UME 29063. (C,E,F). UME 29068.



which deserve some comments.

According to Funk (l.c.) the ascomal wall should be composed of textura epidermoidea. A more accurate description is textura intricata with cells separated by a gelatinous substance.

Funk (l.c.) described the paraphyses to be "not swollen at the tips, 1-2 µm diam." Actually, they are a little swollen and ca. 2-3 µm at the tips, whereas the rest of the filaments in the hamathecium are only ca. 1-2 µm diam. This may explain the discrepancy between Nannfeldt´s and Rehm´s observations (see Nannfeldt 1932: 325). The hamathecium in **Lahmia kunzei** is remarkable, and I have examined sections and squash mounts of numerous immature and mature ascomata in order to check whether there really are paraphyses with free ends and not merely broken paraphysoids. There is no doubt that there are. The ends are rounded and the cells are often of uneven thickness. Young, immature ascomata contain only paraphysoids, and the paraphyses must develop secondarily from paraphysoids in the upper part of the hamathecium during the ontogenesis. In mature ascomata the slightly swollen tips are glued together by faintly brownish, amorphous, covering grains.

According to Funk (l.c.), the asci should be unitunicate, but with a markedly thickened ascus tip, giving the appearance of a bitunicate ascus. "At dehiscence, the contents of the ascus compress the thickening and burst through the ascus wall, which shows some elasticity at this point but which has no preformed pore". Nothing is mentioned about asci becoming loose and squeezed out from the ascomata. It is possible that the whole ascus functions as a diaspore, and that it opens in some way outside the ascoma. Morphologically the ascus is bitunicate, but it may have lost the fissitunicate function.

Systematical position

Problems immediately arise when attempting to refer this species to an order in any of the recent classifications of the ascomycetes. Eriksson & Hawksworth (1985) accepted 43 orders in their latest "Outline of the ascomycetes". Comparisons with **Lahmia** gives the following results.

Orders 1-8 consist of discolichens, most of which have disc-like apothecia, others with hysteriform lirellae, a few with perithecioid apothecia. Nannfeldt (1932: 324) stated that **Lahmia** was originally referred to the lichens, but that Rehm (1890: 341) treated it among non-lichenized fungi. Nannfeldt meant that the ascomata were built as those in Lecanorales, although they do not exhibit the positive Iodine reaction. The ascomata of **Lahmia kunzei** are hemiangiocarpous. This type of development characterizes the orders 3-8, but in none of these lichen orders do the ascoma, hamathecium (paraphysoids + "paraphyses"), asci, etc. show any overall agreement with the structures in **Lahmia**. **Lahmia** can not be a non-lichenized member of any of these orders. Any similarities with true lichens are casual only. Thus, superficially similar asci (though I+) with spirally twisted, nematode-like spores occur in the genus **Sarrameana** (Vezda & James 1973: 305), but the ascomata are typical, gymnocarpous, disc-like apothecia in this genus. Ascomata with stalked, globose fertil head occur in order 8 (Caliciales). In fact, **Lahmia** was originally referred to this group of lichens by Körber, but none of the genera accepted by Tibell (1984) in Caliciales has the same type of ascomal wall, hamathecium, asci, or spores as **Lahmia**.

Orders 9-14 contain non-lichenized discomycetes (the Schaereriaceae, tentatively placed in Pezizales, and Baeomycetaceae, in Leotiales, are lichenized). Order 9 (Pezizales) differs, e.g in having usually large, fleshy, bright-coloured apothecia, usually operculate asci, and hamathecium of paraphyses. In the Sarcosomataceae the paraphyses anastomose at the bases, but there are no other similarities with **Lahmia**. Some species in the order have secondarily closed ascomata, but they are all large and truffle-like and therefore inconsistent with **Lahmia** in this context. Order 10 (Elaphomycetales) are truffle-like fungi. Order 11 (Cyttariales) are parasites on **Nothofagus**, with quite different ascomata, hamathecium, asci, etc. Order 12 (Leotiales) contains the bulk of the inoperculate, ascohymenial discomycetes. The ascomata are usually typical apothecia with naked hymenium of asci and paraphyses, never paraphysoids. Order 13 (Medeolariales) contains only one species, a parasite on leaves of **Medeola**, lacking differentiated ascomata, having true paraphyses, dark-coloured, ornamented ascospores, etc. Gordon (1966, 1968) recognized three types of centrum development in the Hypodermataceae, i.e. the bulk of order 14 (Rhytismatales). In type I (**Lophodermium juniperinum** (Fr.) De Not.) the hamathecium consists of paraphysoids in young ascomata. In a later stage they become free from the covering clypeus and develop paraphyses from the free ends. This development is thus similar to that in **Lahmia**, but there are so many differences between these taxa that a close relationship is very improbable. In Rhytismatales, the ascomata are immersed in a stroma or host tissue and are often provided with a clypeus, but they are never stalked as in **Lahmia**. The mature hamathecium consists exclusively of paraphyses, not mainly of paraphysoids as in **Lahmia**. The ascus morphology varies greatly within the order (Minter & Cannon 1984: 65), but never agrees with the morphology of the **Lahmia** asci. In fact, **Lahmia** has no close resemblance to any of the members in orders 9-14, and the genus can not be included in any of these orders.

Orders 15-28 are unitunicate or secondarily pseudoprototunicate pyrenomycetes. Rather thick-walled, functionally unitunicate asci occur in some representatives of order 15 (Diaporthales), but the endotunica usually contains an apical ring and the asci are not long-stalked as in **Lahmia**. Moreover, paraphysoids and initially closed, turbinate ascomata are unknown in that order. Order 16 (Sordariales) includes in current classifications the order Coronophorales. Funk (1976: 871) referred his new genus **Parkerella** (= **Lahmia**) to that order (= Nitschkiaceae in Sordariales). He stated that it resembles **Thaxteria** in its long-stalked asci with 3-septate spores. He pointed out that the ascomata are turbinate in both genera, but the tissues are pseudoparenchymatous in **Thaxteria** and not plectenchymatous. Moreover, there should be paraphyses in **Parkerella** and no distinct "Quellkörper" above the asci. As mentioned above, the hamathecium consists of paraphysoids and short secondary paraphysis-like filaments in **Lahmia**, but this type of hamathecium does not occur in the Nitschkiaceae. Moreover, in all members of the latter family the ascomal wall consists of large, ± isodiametric, dark-coloured cells with characteristic "Munk pores" (inner cells may be smaller and hyaline). The similarities in ascus shape and spore septation are only casual, and **Lahmia** is certainly not related to either Nitschkiaceae or any other family in Sordariales. Orders 17 and 18 (Microascales and Ophiostomatales) contain small perithecioid ascomata without hamathecium, small evanescent asci, small non-septate ascospores, etc. Order 19 (Diatrypales) are ostiolate, commonly stromatic pyrenomycetes with I+ ring in the asci, and non-septate, allantoid spores. Order 20 (Xylariales) have ascohymenial, perithecioid ascomata, as a rule, with I+ ring in the asci with dark-brown spores with germ slit. Order 21 (Amphisphaeriales) are also ostiolate, ascohymenial pyrenomycetes, differing from the previous order in ascus and ascospore morphology. Most species in order 22 (Halosphaeriales) are marine and have perithecioid ascomata with usually evanescent hamathecium and asci. The spores are often provided with characteristic gelatinous equipments. Rather long-stalked asci occur in some **Calosphaeria** species, order 23 (Calosphaeriales), but again, the hamathecium is different (broad and tapering paraphyses), asci are attached to basal parts of paraphyses, ascomata are perithecioid and have a periphysate ostiole, etc. Order 24 (Trichosphaeriales) have ostiolate perithecia, which are setose in many genera. The hamathecium is lacking or may consist of paraphyses and periphyses. Paraphysoids are reported for the genus **Porosphaerellopsis** (Samuels & Müller 1978: 128, as **Porosphaeria**), but there is a periphysate ostiole, and the asci and spores are quite different from those in **Lahmia**, and these taxa are very remote. Order 25 (Phyllachorales) contains ostiolate, ascohymenial, immersed pyrenomycetes. In order 26 (Hypocreales) the ostiolate, light-coloured perithecia are usually immersed in a stroma. Asci are thin-walled and short-stalked, and the hamathecium usually consists of periphysoids, not paraphysoids. Order 27 (Eurotiales) have non-ostiolate ascomata, but they are usually not stalked, and the centrum is quite different from that in **Lahmia**, with small globose, pseudoprototunicate asci, and many other differences. Order 28 (Clavicipitales) are light-coloured, usually stromatic fungi. The perithecia are ostiolate and the very long and narrow asci have a semi-globose thickening in the top, pierced by a narrow pore. From the above it is clear that **Lahmia** is very different from all pyrenomycetes with functionally unitunicate asci.

Orders 29-34 contain bitunicate ascomycetes. **Lahmia kunzei** may be a bitunicate ascomycete, which has lost the "Jack-in-the-Box" opening mechanism. Hamathecium of paraphysoids is known in all six orders, except for in Verrucariales (periphysoids). However, the ascomata are apothecioid in three of the orders (29-31), peritheciod in the three others (32-34), but in none of them are they turbinate, closed and open irregularly. **Philippsiella atra** Cooke (Philippsiellaceae, Patellariales) has a superficial resemblance, but the anatomy of the ascomata and the small ellipsoidal asci are quite different. **Seuratia** spp. (Seuratiaceae, ?Arthoniales) have a thallus with cells embedded in thick gel, but the genus is certainly not closely related to **Lahmia**. Bundles of asci are laid down anywhere in the thallus, and they are not enclosed in a hamathecium and there is no ascomal wall separating the asci from the vegetative thallus. **Lahmia** is out of place also in the large and heterogeneous order Dothideales. **Coccoidea** Henn., parasitic on **Quercus** leaves, has circular, truncate ascomata, penetrating the host with a stipe (Eriksson 1981:

45), but the resemblance is superficial. The ascomata are multi-loculate, open by pseudostioles and have pseudoparenchymatous walls. The asci resemble those of **Lahmia** a little, but they are much more short-stalked, extrude a part of the endotunica upon dehiscence, and contain ovoid apiospores. Another family to consider is Tubeufiaceae. The hamathecium of **Tubeufia** consists of paraphysoids (Samuels, Rossman & Müller 1978: 184). The asci are stalked and contain several-septate ascospores. However, the ascomata open by a pseudostiole, and the surface cells of the ascomal wall are circular, elliptic or angular in outline. All species seem to have an anamorph.

Orders 35-43 (yeasts, Taphrinales, Laboulbeniales, etc.) can all be left out of consideration. None of the species in these orders has the slightest resemblance to **Lahmia kunzei**.

The conclusion that follows from this discussion is that **Lahmia** can not be included in any of the currently recognized orders. The genus must be referred to a new family in a new order. It was listed among genera of uncertain affinities by Eriksson & Hawksworth (1985: 49-55). None of the other genera in this large group seems to be closely related to **Lahmia**. Therefore, a new monotypic family and order is described.

I am not sure whether it is possible to use the names Lahmiaceae and Lahmiales, as there are the older homonyms Lamiaceae and Lamiales, based on **Lamium** L. (Phanerogamae). The only other names which could be considered for basionyms are **Parkerella** A. Funk, **Parathalle** Clem., and **Lahmiomyces** Cif. & Tomas. As mentioned above, there is an older homonym of **Parkerella** A. Funk. **Parathalle** is no longer included in **Lahmia**. The type species, **P. fueistingii** (Körber) Clem. (= **Lahmia fueistingii** Körber), is a synonym of **Arthrorhaphis grisea** Th. Fr. (Poelt & Hafellner 1976: 219). **Lahmiomyces**, based on **Lahmia picea** Anzi, is not related to **Lahmia kunzei** (cf. Rehm 1890: 343). It is a member of the Patellariaceae. The anatomy of the ascomal wall resembles that in **Lahmia**, but the asci and the paraphysoids are arranged in a hymenium covered by a thin epithecium. The asci do not become loose in mature ascomata. The genus will be treated more in detail in another paper.

This means that there is no generic name available for constructing the names of the higher taxa if Lahmiaceae and Lahmiales are considered homonyms of Lamiaceae and Lamiales. The ICBN gives no instructions about how to proceed with homonyms of family names. I have decided to use the names Lahmiaceae and Lahmiales, but this case should be discussed by the General Committee of the Nomenclature Section at the Berlin Congress in 1987, and if these names are not accepted, I suggest that they are changed into Mycolahmiaceae and Mycolahmiales (based on **Lahmia** prefixed with "Myco-").

Lahmiaceae O. Eriksson fam. nov.
Ascomata stipitata, turbinata, non ostiolata, uniloculata. Paries e textura intricata compositus, fissuris radialibus inaequalibus dehiscens. Hamathecium e paraphysoidibus et apicem versus e filamentis paraphysium similibus compositum. Asci bitunicati, longe stipitati. Sporae hyalinae, septatae.
Typus: **Lahmia** Körber

Lahmiales O. Eriksson ordo nov.
Characteres Lahmiacearum praebentes.
Typus: **Lahmiaceae** O. Eriksson

Lahmiaceae O. Eriksson fam. nov.
Ascomata stalked, turbinate, non-stiolate, uniloculate. Wall of textura intricata, opening irregularly by radial fissures. Hamathecium of paraphysoids and apically of paraphysis-like filaments. Asci bitunicate, long-stalked. Ascospores hyaline, septate.
Type: **Lahmia** Körber.

Lahmiales O. Eriksson ordo nov.
Characters as in Lahmiaceae.
Type: **Lahmiaceae** O. Eriksson

BIOLOGY

The Swedish specimens of **Lahmia kunzei** on **Populus tremula** (closely related to **P. tremuloides**; see, e.g. Krüssman 1962: 227) were only found on rough bark in fissures on aspen stems. Ascomata were never found on smooth bark or on naked wood in fissures. The fungus was reported (as **Parkerella populi**) on cork bark of **Populus tremuloides** from the central interior of British Columbia, Canada, and it was usually found in association with **Rhytidiella baranyayi** (Funk 1976: 868). The latter fungus was described by Funk & Zalasky (1975: 752) and believed to be the real cause of the cork bark disease. The etiology of the disease on **P. tremula** deserves more studies. **Lahmia kunzei** is certainly not the cause of the cork bark and the fissures. It is wide-spread in Europe. I have seen herbarium material (UPS) from Italy in the South to Finnmark in northern Norway in the North. According to Rehm (1890: 342), the fungus occurs on bark of **Populus alba** and **P. tremula**, but also, though more rarely, on **Salix**, **Robinia** and **Quercus**. In the Nordic countries it has only been found on **Populus tremula**. Two samples of **L. kunzei** on **P. alba** collected by Lahm in Germany are filed in UPS. There are no morphological differences between ascomata from **P. alba** and **P. tremula**.

SWEDISH MATERIAL STUDIED

(1). Västerbotten, Vännäs par., ca. 1 km E. of Harrselsfors power station, E. slope of the Ume River, 6.IX. 1985, leg. O.E. (UME 29061); 18.V.1986 (UME 29068). - The fungus occured on trees in a sheltered position at the base of a steep slope. There were about 10 trees, all showing symptoms of cork bark disease. Some of the trees had very extensive fissures in the bark, with cork bark near naked wood. Several other fungi occurred on the bark, e.g. **Troposporella fumosa** Karsten. Aspens in a ravine near this locality were all healthy.

(2). Västerbotten, Umeå, Sörfors, mixed forest (**Betula**, **Populus**, **Picea**, etc.) at the Ume River, 27.IV.1986, leg. O.E. (UME 29063), 17.V.1986 (UME 29064). - Cork bark was seen around dead twigs and large fissures on the stem. The ascomata of **Lahmia kunzei** were not quite mature in April 1986, but contained mature, 3-septate spores in mid-May.

(3). Västerbotten, Umeå, Brännland, steep, sunexposed slope at the Ume River near the outlet of Rupbäcken, 18.V.1986, leg. O.E. (UME 29065);

(4). Västerbotten, Umeå, Between Ytterrödå and Heleneborg, 19.V.1986, leg. O.E. (UME 29066, 29067). In locality (4) **Lahmia kunzei** was found on two aspens in a spruce forest, very near the place where **Rhytidiella moriformis** was encountered in 1975. The large aspen trees with this fungus could no longer be found, and most of the spruces have also been removed. **Rhytidiella moriformis** was searched for, but could not be refound.

Numerous other collections of **Lahmia kunzei** from other provinces in Sweden (S, UPS) were examined and verified with the dissecting microscope.

ACKNOWLEDGEMENTS

I am grateful to Prof. Dr. R.P. Korf for the loan of North American material of **Parkerella populi**, to Prof. Dr. R. Santesson, Dr. L. Holm, and Dr. V. Shindler for reviewing the manuscript, to Dr. L. Holm for correcting the Latin diagnosis, and to Dr. Yue Jing-zhu for drawings (Fig. 2 A, C, D).

LITERATURE CITED

ERIKSSON, O. 1981. The families of bitunicate ascomycetes. - Opera Bot. 60: 1-220.

- & HAWKSWORTH, D.L. 1985. Outline of the ascomycetes - 1985. - Systema Ascomycetum 4: 1-79.

FARR, E.R., LEUSSINK, J.A. & STAFLEU, F.A. 1979. Index Nominum Genericorum (Plantarum). II. - Regnum Veget. 101: 631-1276.

FUNK, A. 1976. Parkerella, a new genus of Coronophorales. - Can. J. Bot. 54: 868-871.

- & ZALASKY, H. 1975. Rhytidiella baranyayi n.sp., associated with cork-bark of aspen. - Can. J. Bot. 53: 752-755.

GORDON, C.C. 1966. Ascocarpic centrum ontogeny of species of Hypodermataceae of conifers. - Amer. J. Bot. 53: 319-327.

- 1968. Ascocarpic centrum ontogeny of species of Hypodermataceae of conifers. II. - Amer. J. Bot. 55: 45-52.

KÖRBER, G.W. 1859-1865. Parerga Lichenologica. - Breslau.

KRÜSSMANN, G. 1962. Handbuch der Laubgehölze. II. - Parey, Berlin & Hamburg, 608 pp.

MINTER, D.W. & CANNON, P.F. 1984. Ascospore discharge in some members of the Rhytismataceae. - Trans. Br. mycol. Soc. 83: 65-92.

NANNFELDT, J.A. 1932. Studien über die Morphologie und Systematik der nicht-lichenisierten, inoperculaten Discomyceten. - Nova Acta R. Soc. Scient. upsal., ser. IV 8(2): 1-368.

POELT, J. & HAFELLNER, J. 1976. Die Flechte Neonorrlinia trypetheliza und die Familie Arthrorhaphidaceae. - Phyton 17: 213-220.

REHM, H. 1887-1896. Die Pilze. Ascomyceten: Hysteriaceen und Discomyceten. - In: Rabenhorst, L., KryptogFlora Deutschl., Österr. und Schweiz 1(3): I-VIII, 1-1275.

SAMUELS, G.J. & MÜLLER, E. 1978. Life-history studies of Brazilian ascomycetes 1. Two genera of the Sphaeriaceae having, respectively Sporoschisma-like and Codinaea anamorphs. - Sydowia 31: 126-136.

-, ROSSMAN, A. & MÜLLER, E. 1978. Life-history studies of Brazilian ascomycetes. Three species of Tubeufia with, respectively, dictyosporous/pycnidial and helicosporous anamorphs. - Sydowia 31: 180-193.

TIBELL, L. 1984. A reappraisal of the taxonomy of Caliciales. - Beih. Nova Hedwigia 79: 597-713.

VEZDA, A. & JAMES, P. 1973. Sarrameana paradoxa A. Vezda & P. James gen. nov. et sp. nova, eine bemerkenswerte Flechte aus Neu-Kaledonien. - Preslia (Praha) 45: 305-310.

ZALASKY, H. 1968. Rhytidiella moriformis n. gen., n. sp. causing rough-bark of Populus balsamifera. - Can. J. Bot. 46: 1383-1387.

- 1975. Cell deformities in bark and sapwood caused by Rhytidiella moriformis and Keissleriella emergens infections in poplar. - Can. J. Bot. 53: 780-783.

MYCOTAXON

Vol. XXVII, pp. 361-375 October-December 1986

CULTURAL STUDIES IN TUBULICRINIS AND XENASMATELLA (CORTICIACEAE, BASIDIOMYCETES)

Nils Hallenberg

Department of Systematic Botany
Gothenburg University, S-413 19 Göteborg, Sweden

ABSTRACT. Cultural characters are reported for six species of Tubulicrinis (**T. borealis, T. calothrix, T. gracillimus, T. medius, T. strangulatus, T. subulatus**) and two species of Xenasmatella (**X. allantospora, X. tulasnelloidea**). Intercompatibility tests between a number of specimens have been carried out to assess the variation in substrate and habitat preference and geographical distribution. Interincompatible sibling species have been found in five of the studied species.

INTRODUCTION. Very little information exists on cultural characters and intercompatibility matings in the genera Tubulicrinis and Xenasmatella (Boidin 1958, Hallenberg 1984). Consequently, such data has hitherto been unavailable for taxonomical decisions.

The present investigation reemphazises the homogenity within respective genera as far as the investigated species are concerned. Further, the results from intercompatibility tests have been used to assess variation in fruitbody morphology, substrate and habitat preference and geographical distribution. Several sibling species were detected within the investigated material, but no new species are described. In this study, groups of compatible specimens are considered sibling species when they are genetically isolated from each other (interincompatible) and when there are no significant morphological differences between their fruitbodies. All siblings found here will be determined as respective "morphological species" when using the keys constructed by Eriksson et al. (1987) and Jülich (1984).

It is important to obtain more knowledge of sibling species complexes for the understanding of speciation processes. Before describing the entities as species with Latin binomials it is necessary to have a more precise knowledge of characters other than morphological ones (substrate preference, geographical distribution, etc.). Moreover, I do not see any contradiction in accepting a "biological species concept" and application of a "practical standard of a species" as defined by Parmasto (1985). The latter term reflects the present knowledge of a species. In this paper, the different siblings will be referred to different "types" within a (morphological) species.

This investigation is made in connection with the flora project "Corticiaceae of North Europe" and references concerning the treated species are given in this flora (Eriksson et al., 1987).

METHODS. The specimens originate in Austria, Canada, Denmark, Norway, Romania, and Sweden. They have been carefully compared with types or other representative material. When spore measurements are given these have been made from spore prints. Single-spore (SS)-cultures and polyspore (PS)-cultures were isolated after dispersal on common malt agar. To determine the breeding ability (i.e., the ability to form clamps in matings) of the individual SS-cultures, matings between SS-cultures of each specimen were first made. Compatible mating types from one specimen were mated with compatible mating types from the other specimens. In some cultures it was impossible to obtain compatible mating types. However, such SS-cultures have been accepted if they were compatible in matings with cultures from other specimens. Further, in other specimens it was possible to indicate the polarity pattern. Formation of clamps in matings was looked for after that the mycelia had been in contact for 6-8 weeks.

Culture characters of the PS-mycelia were analyzed after 3 and 6 weeks growth. Culture codes are from Nobles (1965) with emendations by Boidin and Lanquetin (1983). Drop tests for extracellular oxidases (Syringaldazine, Gum Guaiac, Guaiacol, 1-Naphtol, p-Cresol, L-Tyrosine) follow Marr (1979). Nuclear staining was made with Giemsa according to Boidin (1958). Terminology of nuclear behaviour refers to Boidin and Lanquetin (1984) as well as earlier reports by Boidin.

In the lists of "material" (below, under each species) information concerning the studied specimens are given. Such data are cathegorized by slanted lines: Culture number/ substrate/ locality/ number of available SS-(PS-)cultures or SS-numbers of compatible mating types. Compatible mating types are separated by a slant line, "/".

Cultures are stored in the culture-collection at the Department of Systematic Botany, Gothenburg University. The GB-numbers refer to the culture-collection. The original specimen together with spore-print can be identified by the same number and are kept in the herbarium (GB).

RESULTS OF CULTURAL STUDIES AND COMPATIBILITY TESTS.

Tubulicrinis borealis John Erikss.

Material:
GB 339/ Picea/ Sweden, Närke/ 4 SS.
GB 439/ Picea/ Sweden, Västergötland/ 1/4.
GB 795/ Pseudotsuga/ Canada, B.C., Vancouver Island/3 SS.

Compatibility between these specimens has previously been shown (Hallenberg, 1984). In the present study, these cultures proved incompatible with specimens representing the closely related species T. strangulatus. Altogether 26 negative confrontations recorded.
According to Eriksson et al. (1987), T. borealis has a mainly northern distribution in North Europe and occurs on decorticated, coniferous wood (as did the tested specimens). It seems to be associated with brown-rotted wood.

CULTURE CHARACTERS (GB 439): Fig. 1A, 2A
Aerial mycelium absent to downy (in old parts). Advancing zone even, appressed. Ordinary branching hyphae, clamped at all septa, with thin to slightly thickened walls, 1.5-3 µm wide in the margin , up to 7 µm wide in old parts and partly with irregular outlines (fig. 2A); no staining in Melzer.
Colony radius 21 mm after 6 weeks.

CODE:
1. 3c. (7). (26). 32. 36. 38. 47. 55. 58. 61.
OXIDASE REACTIONS: All tests negative.
POLARITY: Heterothallic, type of polarity unknown.
CYTOLOGY: SS-mycelium with uninucleate cells, PS-mycelium dicaryotic.
NUCLEAR BEHAVIOUR: Normal.

T. calothrix (Pat.)Donk

Material:
GB 341/ Pinus/ Sweden, Småland/ 1,3,4/2,5.
GB 357/ Populus/ Sweden, Uppland/ 1,2,3/6,7.

Compatibility has been found between these two specimens. Morphologically they are in accordance with the descriptions given by Eriksson et al. (1987). T. calothrix is there reported as fairly common in N. Sweden, becoming more rare towards the S. parts.
The specimens in this compatibility group were collected in the S. parts of N. Europe. It is interesting to note that GB 357 was collected on a substrate other than coniferous wood.

CULTURE CHARACTERS (GB 357): Fig. 1G, 2B
Aerial mycelium absent. Advancing zone even, appressed. Ordinary branching hyphae, with clamps at all septa, with

thin to slightly thickened walls, 1.5-6 µm wide, with scattered capitate hyphal endings in old mat (globule up to 13 µm in diam.). Moreover, hyphae in the old mat are frequently somewhat moniliform (fig. 2B). At some septa, constriction of the hypha (fig. 2B) is found, which is a feature commonly found in Hyphodontia. No reaction with Melzer. Colony radius 18 mm after 6 weeks.

CODE:
2a. 3c. (7). (26). 32. 36. 38. 47. 54. (55). 58. 61.
OXIDASE REACTIONS: Syringaldazine, 1-Naphtol, Gum Guaiac, and Guaiacol positive. p-Cresol and L-Tyrosine negative.
POLARITY: Heterothallic, type of polarity unknown.
CYTOLOGY: SS-mycelia with uninucleate cells, PS-mycelium dicaryotic.
NUCLEAR BEHAVIOUR: Normal.

T. gracillimus (Rog. & Jacks.)G.H. Cunn.
Syn.: T. glebulosus (Bres.)Donk

Material:
GB 417/ Pinus/ Austria, Steiermark/ 1 PS.
GB 285/ Betula/ Sweden, Torne Lappmark/ 1,4,5/2,6.
GB 787/ Populus/ Canada, Quebec/ 2/3.
GB 912/ Betula/ Sweden, Lycksele Lappmark/ 1,9,10/3.
GB 1251/ Picea/ Norway, Oppland/ 4/5.
GB 1253/ Picea/ Norway, Oppland/ 3/2,4,5.

Three compatibility groups have been discerned between which there is complete incompatibility: A) GB 417; B) GB 1251, GB 1253; C) GB 285, GB 787, GB 912. Altogether 32 negative confrontations recorded.
Only minor morphological differences exist between these three groups and in the keys of Eriksson et al. (1987) and Jülich (1984) all will be determined as T. gracillimus. Although very little material is available the following separating characters of the fruitbodies may be useful in the search for delimitation of the sibling species:

A) Substrate: coniferous wood (Pinus). Spores size: 8,5-9.5 X 2 µm. Subiculum and context is mainly composed of thick-walled skeletals and clamped generative hyphae with thickened walls, interwoven in a rather loose texture. There are numerous transitions between these two kinds of hyphae as well as between skeletals and lyocystidia. A high proportion of the lyocystidia are enclosed, while some project beyond the hymenial surface. Lyocystidia are moderately amyloid, skeletals are weakly to not-amyloid, 3-4 µm wide, with a narrow lumen, occasionally branched.

B) Substrate: coniferous wood (Picea). Spore size: 7-8 x 1.8-2 µm. Fruitbodies rather thin; hyphae in subiculum and context rather thin-walled, interwoven; skeletals absent. Hyphae in the subiculum and adjacent part of the context may be weakly or not amyloid. Lyocystidia moderately amyloid, distinctly projecting.

C) Substrate: deciduous wood (Betula, Populus). Spore size: 6-8 x 1.8-2 µm. In the subiculum and adjacent part of the context, scattered skeletals are found together with generative hyphae with thickened walls. These may all be weakly or not amyloid. Context hyphae with a pronounced vertical orientation. Lyocystidia rather weakly amyloid, embedded or projecting.

The morphological differences, differences in substrate preference, as well as the results from the intercompatibility tests indicate that these three groups represent different and distinct species. Hjortstam (1979) also reports that Nordic material of T. gracillimus is heterogenous and probably includes more than one taxon.

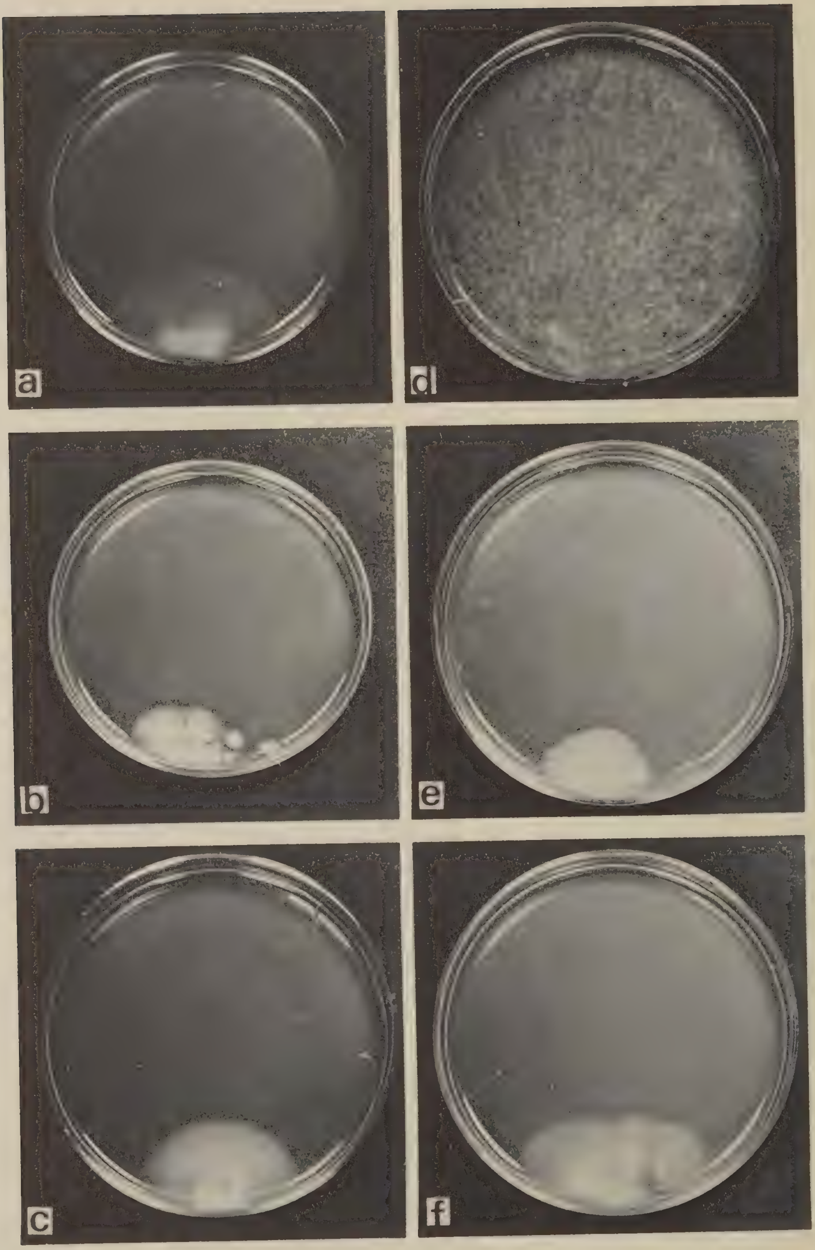
The sibling species reported here should be referred to as "coniferous type A" (GB 417), "coniferous type B" (GB 1251, GB 1253), and "broad-leaved type" (GB 285, GB 787, GB 912).

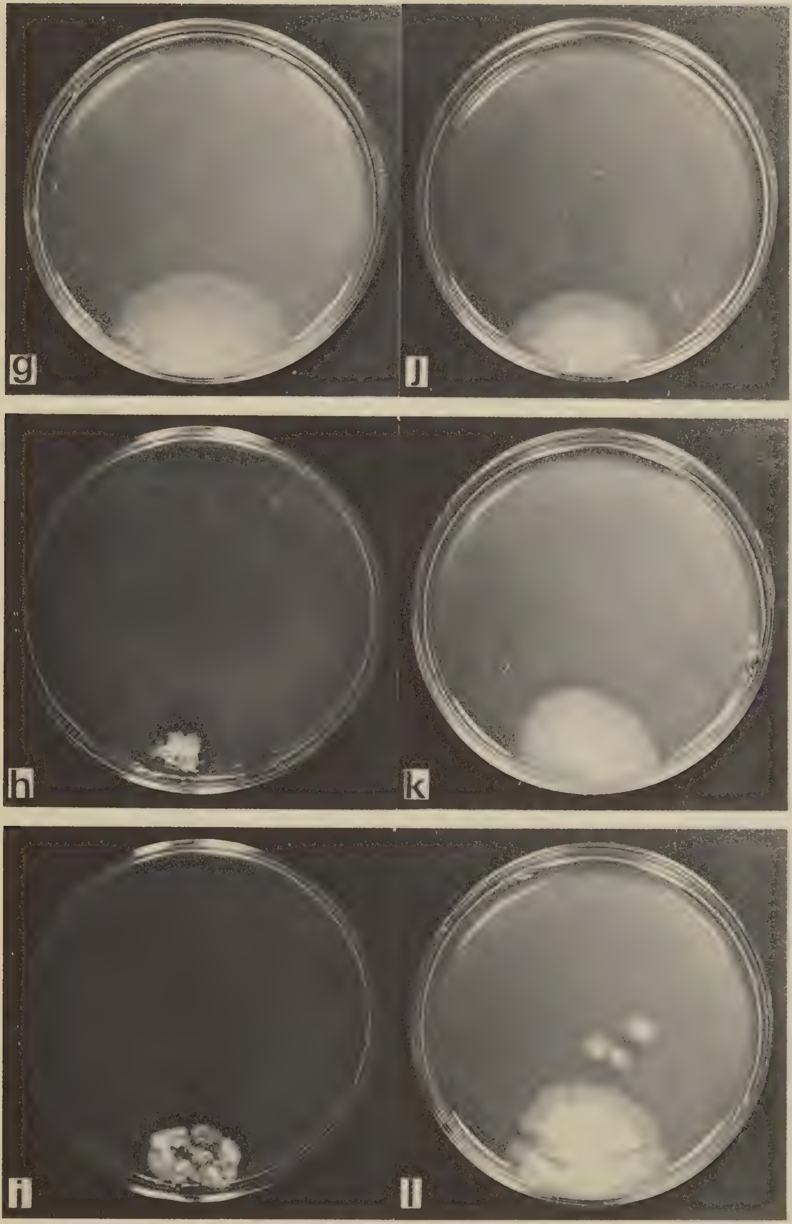
CULTURE CHARACTERS (GB 417 = coniferous type A):
Fig. 1D, 2C
Aerial mycelium downy, whitish granules in agar. Advancing zone even, appressed. Ordinary branching hyphae, clamped at all septa, with thin to slightly thickened walls, 1.5-7 µm wide but a distinct difference between "narrow" and "wide" ones. Thick-walled, ellipsoidal chlamydospores, 9-12 X 6-10 µm, with light refracting contents (with phase contrast), formed in chains, abundant in the granules (fig. 2C). No reaction in Melzer.
Plates covered in 6 weeks.

CULTURE CHARACTERS (GB 1253 = coniferous type B; GB 912 = broad-leaved type):
Fig. 1E,F, 2D
Aerial mycelium absent to downy (in old parts). Advancing zone even to slightly bayed, appressed. Ordinary branching hyphae, with clamps at all septa, with thin to slightly thickened walls, 1.5-4 µm wide, constricted at some septa (as like in Hyphodontia), in old parts some hyphae irregularly swollen (up to 11 µm wide; fig. 2D). No reaction with Melzer.
Colony radius after 6 weeks: 15 mm (in GB 912), 10 mm (in GB 1253).

CODES:
GB 417: 1. 3. 7. 34. 36. 38. 46. 55. 64.
GB 1253: 2a. (2b). 26. 32. 36. 38. 47. 55. 58. 61.
GB 912: 2a. (2b). 26. 32. 36. 38. 47. 54. 58. 61.

Fig. 1. Cultures after six weeks growth. a) Tubulicrinis borealis, GB 439, b) T. medius, GB 976, c) dito, GB 338, d) T. gracillimus "coniferous type A", GB 417, e) T. gracillimus "coniferous type B", GB 1253, f) T. gracillimus "broad-leaved type", GB 912, g) T. calothrix, GB 357, h) T. subulatus "mixed forest type", GB 1292, i) Xenasmatella allantospora "type A", GB 1315, j) Tubulicrinis strangulatus "moderately decayed type", GB 1056, k) T. subulatus "old spruce forest type", GB 1255, l) Xenasmatella tulasnelloidea "Nordic type". - Photos Ellen Hansson.


a
d
b
e
c
f


g
j
h
k
i
l

OXIDASE REACTIONS:

	Syringald.	1-Napht.	Gum G.	Guaiacol	p-Cresol	L-Tyr.
GB 417:	-	-	-	-	-	-
GB 1253:	+	+	+	+	(+)	(+)
GB 952:	+	+	+	+	(+)	(+)

POLARITY: Unknown for GB 417 (no SS-cultures available); heterothallic but type of polarity unknown in GB 1253 and GB 912.
CYTOLOGY: SS-mycelia with uninucleate cells (GB 1253, GB 912), PS-mycelia dicaryotic.
NUCLEAR BEHAVIOUR: Normal (GB 1253, GB 912).

T. medius (Bourd. & Galz.)Oberw.

Material:
GB 338/ Picea/ Sweden, Småland/ 1 PS.
GB 976/ Picea/ Norway, Hedmark/ 2,6/3,7,8.

Compatibility has been found between the two specimens. According to Eriksson et al. (1987) lyocystidia in T. medius may be variably amyloid, even though staining in Melzer in most cases is strong. In the specimens investigated here, the lyocystidia are only weakly amyloid with the exception of the part of the wall that is close to the lumen. This part is characteristically more strongly amyloid.
In other respects, the characters of these two specimens coincide with the concept given in the flora.

CULTURE CHARACTERS (GB 338, GB 976): Fig. 1,B,C, 2E,F
Aerial mycelium downy, in old mats slightly cottony. Advancing zone even, appressed. Ordinary branching hyphae, with clamps at all septa, 1.5-4 µm wide; marginal hyphae thin-walled, their apical parts frequently flexuous and with an irregular outline (fig. 2F); hyphae in the old parts with thickened walls, straight to somewhat flexuous, frequently irregularly widened (up to 11 µm wide; fig. 2E), some hyphal segments in the old parts rather thick-walled and distinctly amyloid.
Colony radius 12 mm after 6 weeks.

CODE:
2a. (2b). 3c. (25). 26. 32. 36. 38. 47. 55. 58. 61.
OXIDASE REACTIONS:

	Syringald.	1-Napht.	Gum G.	Guaiacol	p-Cresol	L-Tyr.
GB 338:	(+)	-	+	-	-	(+)
GB 976:	-	-	+	-	-	-

POLARITY: Heterothallic but type of polarity unknown.
CYTOLOGY: SS-mycelia with uninucleate cells, PS-mycelia dicaryotic.
NUCLEAR BEHAVIOUR: Normal.

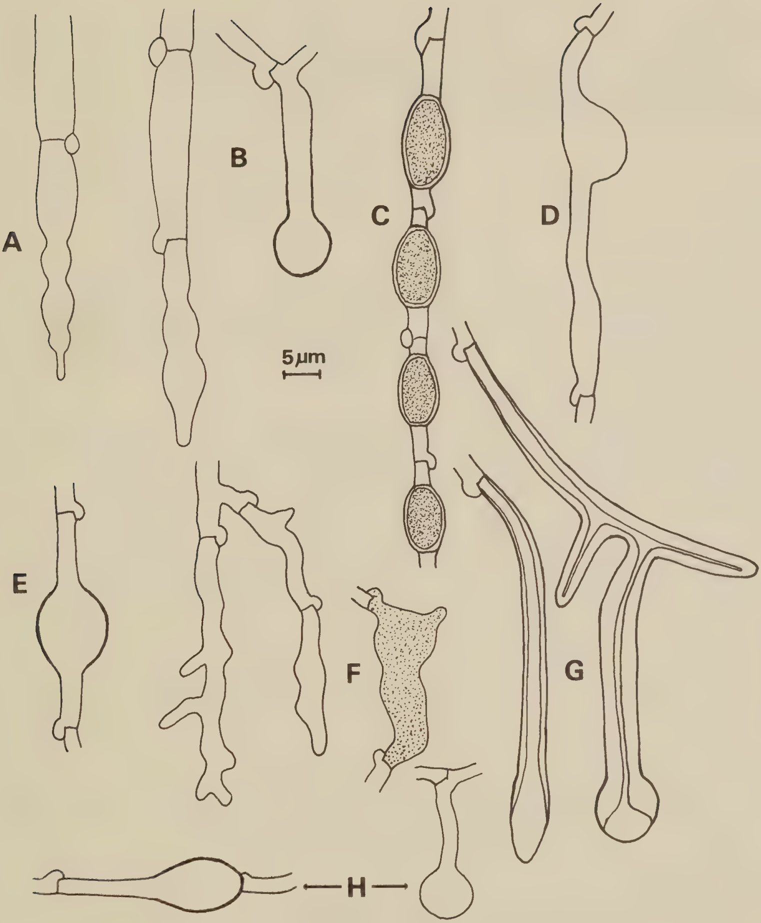


Fig. 2. Culture details in Tubulicrinis (further explanations in text). A) T. borealis, GB 439, B) T. calothrix, GB 357, C) T. gracillimus "coniferous type A", GB 417, D) T. gracillimus "broad-leaved type", GB 912, E) T. medius, GB 338, F) dito, GB 976, G) T. subulatus "old spruce forest type", GB 1255, H) T. subulatus "mixed forest type", GB 1292.

T. strangulatus Larss. & Hjortst.

Material:
GB 905/ Picea/ Sweden, Lycksele Lappmark/ 1,4,5/2,6.
GB 978/ Picea/ Norway, Hedmark/ 1,3,5,6/8.
GB 1056/ Picea/ Romania, Suceava/ 2,3,5/6.
GB 1419/ Picea/ Norway, Oslo/ 8,9/5,6.
GB 1544/ Abies/ Romania, Neamt/ 1/5,6; 2,7,8/3,4.

Compatibility has been found between GB 978, GB 1056, GB 1419, and GB 1544. All these cultures were incompatible with GB 905. Altogether 25 negative confrontations recorded.

The specimens agree in their morphology with the the type specimen and the description given in Eriksson et al. (1987). Little is known about the distribution of T. strangulatus, but as indicated by the intercompatibility tests, the species is widespread and occurs in coniferous forests.

In the morphology, T. strangulatus differs from T. borealis mainly by having slightly broader spores (5-5.5 X 2.5 µm versus 5.5-6 X 2-2.3 µm, when measured from spore-prints) and an inamyloid basidial layer.

Further, there are no noticeable morphological differences in the fruitbodies between GB 905 and the other specimens treated here. On the other hand, there seems to be a difference in substrate preference. While the specimens in the main intercompatibility group have been found on moderately decayed wood (brown-rot), GB 905 was found on strongly brown-rotted wood. The decay with which T. strangulatus is associated is obviously caused by Fomitopsis pinicola (Fr.)Karst.

The sibling species in T. strangulatus should be referred to as "moderately decayed type" (GB 978, GB 1056, GB 1419, GB 1544) and "strongly decayed type" (GB 905).

CULTURE CHARACTERS (GB 1056): Fig. 1K
These agree with those for T. borealis (GB 439; see above) with exception of slower growth in the former (14 mm in 6 weeks versus 21 mm). Moreover, in the tests for extracellular oxidases, no reaction was seen in T. borealis, while some were tests were positive in T. strangulatus.

CODE: 2a. 3c. (7). (26). 32. 36. 38. 47. 55. 58. 61.
OXIDASE REACTIONS: Syringaldazine, 1-Naphtol, Gum Guaiac, and Guaiacol positive. p-Cresol and L-Tyrosine negative.
POLARITY: Heterothallic, tetrapolarity indicated (GB 1544).
CYTOLOGY: SS-mycelia with uninucleate cells, PS-mycelium dicaryotic.
NUCLEAR BEHAVIOUR: Normal.

T. subulatus (Bourd. & Galz.)Donk

Material:
GB 288/ Picea/ Denmark, Jylland/ 1,3,6,7/2,4,5.
GB 363/ Populus/ Sweden, Uppland/ 3/5.
GB 914/ Pinus/ Denmark, Jylland/ 1,4/2.
GB 1073/ Pinus/ Scotland, Perthshire/ 5 SS.
GB 1292/ Picea/ Sweden, Halland/ 1/5,6; 3/2,4.
GB 1353/ Picea/ Sweden, Gotland/ 1/2.
GB 496/ Abies/ Canada, B.C./ 9 SS.
GB 1255/ Picea/ Norway, Oppland/ 1/4.
GB 1546/ Picea/ Romania, Brasov/ 1,2,4,8/6.

Two compatibility groups have been found:
I: GB 288, GB 363, GB 914, GB 1073, GB 1292, GB 1353;
II: GB 496, GB 1255, GB 1546.
Complete incompatibility found in matings between representatives from each group (sibling species). Altogether 28 negative confrontations recorded.

According to the delimitation of T. subulatus given in Eriksson et al. (1987), lyocystidia in the fruitbodies are variable. Apices of lyocystidia may be subulate to mucronate and their walls may be inamyloid - light greyish - weakly amyloid, when treated with Melzer. This variation exists in both of the compatibility groups treated here. The only indications of differences between the siblings seem to be in their habitat preference. While group I has been found in mixed or cultivated forests, the two representatives of group II were collected in old spruce forests in montane regions.

Group I should be referred to as "mixed forest type" and group II as "old spruce forest type".

CULTURE CHARACTERS (GB 1292 = "mixed forest type"):
Fig. 1H, 2H
Aerial mycelium downy. Advancing zone slightly fringed - bayed, appressed. Ordinary branching hyphae, with clamps at all septa, thin-walled, 1.5-3.5 um wide; in old parts of the mycelium with frequent swellings on the hyphae, intercalary or terminally, up to 18 um wide.
Colony radius 5 mm after 6 weeks.

CULTURE CHARACTERS (GB 1255 = "old spruce forest type"):
Fig. 1L, 2G
Aerial mycelium downy. Advancing zone even, appressed. Ordinary branching hyphae, with clamps at all septa, 1.5-3.5 µm wide, with thin to slightly thickened walls; hyphae in the margin uniform in diameter, in old parts somewhat irregular; lyocystidia found in old parts of the mycelium, more or less capitate, non-amyloid.
Colony radius 12 mm after 6 weeks.

CODE:
GB 1292: 2a. 2b. 3c. 26. 32. 36. 38. 47. 55. 60. 61.
GB 1255: 2a. 2b. 3c. 13. 32. 36. 38. 47. 55. 58. 61.

OXIDASE REACTIONS: Both GB 1292 and GB 1255 were positive in all tests.
POLARITY: Tetrapolarity indicated for "mixed forest type", heterothallism (polarity unknown) in "old spruce forest type".
CYTOLOGY: In both siblings, SS-mycelia have uninucleate cells, PS-mycelia dicaryotic.
NUCLEAR BEHAVIOUR: Normal.

Xenasmatella allantospora Oberw.

Material:
GB 254/ Pinus/ Denmark, Jylland/ 1/2.
GB 372/ Picea/ Austria, Steiermark/ 3 SS.
GB 399/ Picea/ Austria, Steiermark/ 3/5.
GB 442/ deciduous wood/ Sweden, Västergötland/ 6/9.
GB 1315/ deciduous wood/ Sweden, Gotland/ 1,6/7; 4/3.

Compatibility was demonstrated between GB 372, GB 399, GB 442, and GB 1315. All these specimens were incompatible with GB 254 (16 negative confrontations recorded).
No noticeable morphological differences were observed between the fruitbodies. Spore sizes (when measured from spore prints) varied minutely between the specimens but all were within the limits 4-6 X 1.5-2 µm.

All specimens were found on decayed, decorticated wood either of coniferous or deciduous trees. The habitats were coniferous forests except for GB 1315 (Fraxinus-Betula-Quercus forest) and GB 254 (mixed forest on the sea-shore). The major compatibility group should be referred to as "type A" while GB 254 is "type B".

CULTURE CHARACTERS (GB 372, 1315): Fig. 1I, 3A
Aerial mycelium slightly cottony - subfelty. Advancing zone a little bayed and fringed, appressed. Hyphae thin-walled, sparsely branched in the margin, frequently simple septate, 0.8-1.5 µm wide; hyphae in old parts of the mycelium with clamps at all septa, the clamps are often characteristically flattened, hyphae up to 2 µm wide, frequently densely ramified, with scattered swellings. Brown resinous residues in agar (old parts of mycelium).
Colony radius 8 mm after 6 weeks.

CODE: 2a. (2b). 3i. 11. 26. 32. 36. 48. 47. 54. 55. (60). 61.
OXIDASE REACTIONS: Syringaldazine, 1-Naphtol, Gum Guaiac, Guaiacol positive. p-Cresol and L-Tyrosine negative, except for GB 372 (L-Tyrosine positive).
POLARITY: Heterothallic, tetrapolarity indicated (GB 1315).
CYTOLOGY: SS-mycelia with uninucleate cells, PS-mycelium regularly dicaryotic.
NUCLEAR BEHAVIOUR: Normal.

X. tulasnelloidea (Höhn. & Litsch.)Oberw.

Material:
GB 944/ Fagus/ Denmark, Jylland/ 5 SS.
GB 1164/ deciduous wood/ Sweden, Bohuslän/ 5 SS.
GB 1330/ deciduous wood/ Sweden, Gotland/ 1,2,5/6.
GB 1338/ Fraxinus/ Sweden, Västergötland/1,3/2,5,6.
GB 1360/ Fagus/ Sweden, Dalsland/ 6 SS.
GB 406/ Abies/ Austria, Steiermark/ 1,4/2,3,5.
GB 1532/ Fraxinus/ Romania, Iasi/ 8 SS.
GB 1539/ dec. wood/ Romania, Brasov/ 1,6/2,3,4,5,7.

Two compatibilty groups have been found:
I: GB 944, GB 1164, GB 1330, GB 1338, GB 1360.
II: GB 406, GB 1532, GB 1539.
Complete incompatibility was found between these groups (altogether 48 negative confrontations recorded).
No noticeable morphological differences were detected between the fruitbodies. Spore sizes varied minutely between the specimens of both groups but all were within the limits 4.5-6 X 3.5-4.3 um. All specimens were found on decayed, decorticated, deciduous wood except GB 406, which was found on the bark of Abies. Their habitats were fertile deciduous forests, Fagus-forests or mixed forests with Fagus.
Specimens belonging to group I should be referred to as "Nordic type", group II as "Central European type".

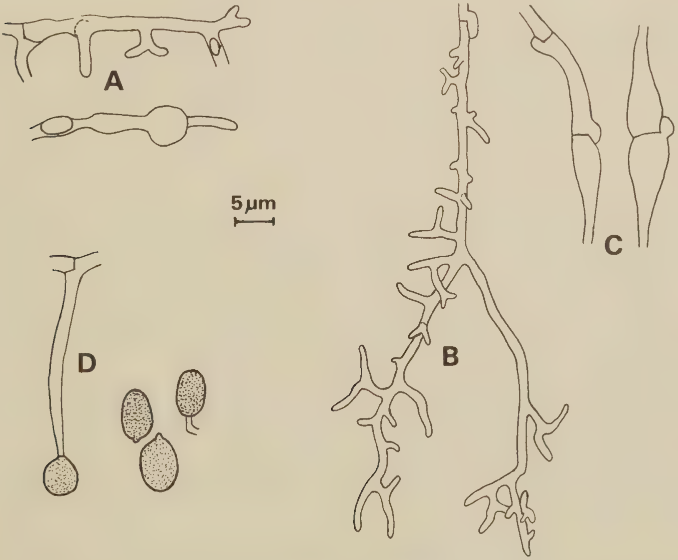


Fig. 3. Culture details in *Xenasmatella* (further explanations in text). A) *X. allantospora* "type A", GB 1315. B - D, *X. tulasnelloidea* "Nordic type", GB 1330; B) racemosely branched hypha, C) ampullate clamps in old mycelium, D) chlamydospores.

CULTURE CHARACTERS (GB 1330, GB 1360 = "Nordic type"):
Fig. 1M, 3B-D

Aerial mycelium absent towards the margin, farinaceous in old parts. Advancing zone slightly bayed, appressed. Hyphae clamped at all septa, thin-walled, clamps often characteristically flattened (fig. 3B); hyphae in the margin very narrow, 0.7-2 µm wide, racemose (fig. 3B); in old parts hyphae frequently widened, especially close to the septa (fig. 3C). Conidia (chlamydospores) subglobose - broadly ellipsoidal, 3-4 X 4-7 µm, uni- to binucleate, rather thick-walled and with light refracting contents (with phase contrast), formed terminally on short side-branches (fig. 3D). Basidia and basidiospores most frequent in a zone between the margin and the chlamysdospore-producing, farinaceous part.
Colony radius 20 mm after 6 weeks.
The cultural characters of *X. tulasnelloidea* were also studied by Boidin (1958), with similar results.

CODE:
2a. 3c. 11. 34. 36. 38. 47. 48. 54. 58. 61.
OXIDASE REACTIONS: Syringaldazine, 1-Naphtol, Gum Guaiac, Guaiacol positive. p-Cresol and L-Tyrosin negative.
CYTOLOGY: SS-mycelia with uninucleate cells, PS-mycelium dicaryotic, conidia binucleate.
NUCLEAR BEHAVIOUR: Normal.

CULTURE CHARACTERS (GB 1532 = "Central European type"):
The only differences between this culture and those representing the "Nordic type" seem to be bigger chlamydospores (7.5-12 x 4-4.5 µm versus 4.5-6 x 3.5-4.3 µm) and a somewhat more rapid growth (35 mm versus 20 mm). No differences were noted in oxidase reactions and cytology.

DISCUSSION

The cultural characters of the species studied to date reaffirms the homogeneity within these two genera. The species of *Tubulicrinis* have slow growth, hyphae with distinct cell walls, with clamps at all septa, and a normal nuclear behaviour. These characters, as well as the features of hyphae, make a relationship to *Hyphodontia* plausible. This relationship is further confirmed by the fruitbody morphology in the two genera.
Xenasmatella allantospora and *X. tulasnelloidea* were been placed in different genera by Jülich (1979). However, it is obvious from the culture characters that they are closely related: slow growth, very narrow hyphae which may be racemosely branched, and characteristically flattened clamps.

ACKNOWLEDGEMENTS

I am indebted to Ellen Hansson, Göteborg, who made the laboratory work and the photos; to K. Seifert, Ottawa, who corrected the English. Financial support was given by the Swedish Natural Science Research Council.

REFERENCES

Boidin, J. 1958: Essai biotaxonomique sur les Hydnés résupinés et les Corticiés. Rev. Mycol. Mém. hors. Sér. 6, 388 pp.

Boidin, J., Lanquetin P. 1983: Basidiomycètes Aphyllophorales épitheloides étalés. Mycotaxon 16 (2): 461-499.

Boidin, J., Lanquetin, P. 1984 a: Répertoire des données utiles pour effectuer les tests d'intercompatibilité chez les Basidiomycètes. I. Introduction. Cryptog. Mycol. Tome 5: 33-45.

Boidin, J., Lanquetin, P. 1984 b: Répertoire des données utiles pour effectuer les tests d'intercompatibilité chez les Basidiomycètes. III. Aphyllophorales non porées. Cryptog. Mycol. Tome 5: 193-245.

Eriksson, J., Hjortstam, Larsson, K-H., Ryvarden, L. 1987: The Corticiaceae of North Europe. Vol. 8 (in manuscript). Fungiflora.

Hallenberg, N. 1984: Compatibility between Species of Corticiaceae (Basidiomycetes) from Europe and North America. Mycotaxon 21: 335-388.

Jülich, W. 1984: Die Nichtblätterpilze, Gallertpilze und Bauchpilze. Kl. Kryptogamenfl. IIb/1 Basidiomyceten. G. Fischer Verlag.

Marr, C.D. 1979: Laccase and Tyrosinase Oxidation of Spot Test Reagents. Mycotaxon 9 (1): 244-276.

Nobles, M.K. 1965: Identification of Cultures of Wood-inhabiting Hymenomycetes. Can. J. Bot. 43: 1097-1139.

Parmasto, E. 1985: The Species Concept in Hymenochaetaceae (Fungi, Hymenomycetes). Proc. Indian Acad. Sci. (Plant Sci.), Vol. 94(2-3): 369-380.

MYCOTAXON

Vol. XXVII, pp. 377-403 October-December 1986

FOLIICOLOUS ASCOMYCETES 7. PHYLOGENETIC SYSTEMATICS OF THE CAPNODIACEAE

DON R. REYNOLDS
Natural History Museum
900 Exposition Boulevard
Los Angeles, California 90007 USA

ABSTRACT

The Capnodiaceae sensu lato is tested as a monophyletic group with compatible character assisted parsimony analyses. Nineteen ascocarpic and hyphal characters are analyzed. The resultant phylogenetic inferences support the recognition of the family Capnodiaceae (Saccardo) Hohnel and three proposed subfamilies Antennularielloideae, Capnodioideae, and Limacinioideae.

A. INTRODUCTION.

Capnodiaceous fungi are a group of ascomycetes which have evolved as inhabitants of the aerial surface of living plants. Both teleomorphic and anamorphic characters have been used to characterize the species since the Capnodiaceae was recognized. The Capnodiaceae sensu lato has been broken into a number of smaller units, largely on the basis of assumed modes of asexual reproduction.

The Capnodiaceae sensu lato was reviewed by Batista and Ciferri (1963) in their monograph on the "Capnodiales". The limitations of the family were based on the antecedents of Arnaud (1911), Berkeley and Desmazieres (1849), Ellis and Everhart (1892), Hohnel (1909, 1910), Montagne (1849), Saccardo (1882), Spegazzini (1918), and Theissen and Sydow (1917), Tulasne and Tulasne (1863). Recent affirmations of this approach have been made by Arx and Muller (1975), Luttrell (1973), and Reynolds (1971, 1978, 1979, 1982, 1985a).

The genera of the Capnodiaceae sensu lato were regrouped by Hughes (1976) in an effort to carry out an avowed predilection for small families (Hughes, 1972). Anamorphic states were proposed as teleomorphic components of groups of capnodiaceous genera on prima facie evidence. Certain elements of the ascocarp centrum were reinterpreted in order to affect a stronger affinity with non-capnodiaceous taxa (Corlett 1970; Hughes, 1976). These groups were given the family names Antennulariellaceae, Capnodiaceae, Euantennariaceae, Metacapnodiaceae, and Triposporiopsidaceae. This concept has been endorsed by Barr (1979, 1983) who spread the taxa of the Capnodiaceae sensu lato through two subclasses of the Loculoascomycetes. Eriksson (1981, 1982) accepted this concept with reservation and united these taxa into one suborder.

I have revised several capnodiaceous genera with a teleocentric focus, i. e. with emphasis on the ascocarpic characters. Several of the smaller taxa have been restored to the Capnodiaceae as a result. For example, *Triposporiopsis spinigera* (Höhnel) Hohnel, the type species of its genus and the family Triposporiopsidaceae Hughes (Hughes, 1976), was synonymized with *Trichomerium* Spegazzini (Reynolds, 1982). *Metacapnodium* Spegazzini and *Ophiocapnocoma* Batista and Ciferri, the two genera of the family Metacapnodiaceae Hughes and Corlett apud Hughes (Hughes, 1972), have been synonymized with *Limacinia* Neger (Reynolds, 1985a).

Hypothesis: The Capnodiaceae sensu lato, including the genera *Acrogenotheca*, *Antennulariella*, *Capnodium*, *Euantennaria*, *Limacinia*, *Limacinula*, *Phragmocapnias*, *Strigopodia*, *Trichomerium*, *Trichopeltheca*, and *Scorias*, comprise a monophyletic group.

B. METHODS.

1. Phylogenetic inference.

Compatiblity assisted parsimony is the strategy used in this critique of the Capnodiaceae sensu lato. The aim of this analysis is to achieve a parsimonious tree in the manner suggested by (Wagner,1984; Farris and Kluge, 1986). A cladogram is constructed on the basis of "good" character states, that is, character states that arise only once. These characters are the compatible characters of Meacham (1981); they are used to construct a convex character state tree. The noncompatible characters identified are then accommodated to the basic skeleton to show secondary cladistic relationships. Two steps are used.

Step 1. Character compatability analysis.

A history of compatibility methods in systematics was reviewed by Meacham and Estabrook (1985). Opposing points of view on this technique have been expressed -- often acrimoniously -- by Duncan (1984, 1986), Churchill et al. (1985), and Farris and Kluge (1985; 1986). No phylogenetic reconstruction made with this method has been found in mycological literature.

The basis of character compatibility analysis is that a character or compatible groups (cliques) of character are hypotheses of evolutionary relationships. Pairs of the 19 characters of the data set of this study were manually tested for compatibility (Meacham, 1981) in order to discover cliques containing the largest number of characters. The level of internal consistency was measured by the ratio of the number of characters in the largest clique to the number of characters in the data set; the fraction approaching unity reflects fewest "false characters".

Duncan (1980), Meacham (1980) and Meacham and Estabrook (1985) emphasized the criterion of "convexity" for an agreement between classification and estimated phylogenetic history. A character state tree asserts that its states are convex. Each character state representing an EU or EUs in a fully convex phylogenetic tree is uniquely connected to a single immediately ancestral state by a line representing some speciation event. According to Meacham and Estabrook (1985), the convexity is demonstrated, "if from any [EU] in the study, any of the other species can be reached by passing along line segments of the phylogenetic tree that pass only through other [EUs] in that same collection. When a [character state tree] asserts that its states are convex, it asserts that the [EUs] in a state share their common property by virtue of inheriting it without change from other species in the same state, and that the common property arose during the speciation of the state's most recent common ancestor."

(2) Parsimony analysis.

Phylogenetic analysis using parsimony as a major criterion developed over the last decade (Eldredge and Cracraft, 1980; Wiley, 1981; Duncan and Stuessy, 1984). The use of cladistics in systematics has become common practice among zoologists and vascular plant taxonomists. Specialists in ferns (Funk, 1984) and mosses (Churchill, 1984) have used this approach. Hoog (1979) made an attempt at fungal analysis with calculation of patristic distances of a preconceived tree.

The most complete phylogenetic work published done in mycology has been by basidiomycete specialists (Høiland, 1983; Vilgalys, 1986). Phylogenetic work with ascomycetes has been abstracted by Currah (1984), Boise (1985) and Reynolds (1985b). Wheeler and Blackwell (1984) provided a concise discussion of cladistical methods and terms using a basic three-species myxomycete model. Eriksson (1981) discouraged the use of cladistics because he supposed a lack of appropriate characters in fungi, although this excellent review of loculoascomycete families amply demonstrates the potential for phylogenetic systematics. Preliminary results of cladistical analysis of the Capnodiaceae was used in a discussion on pleomorphy (Reynolds, 1986).

The parsimony analysis was carried out with Version 2.3 of Phylogenetic Analysis Using Parsimony (PAUP), authored by D. L. Swofford (1984). Several statistics were calculated for each tree. The f-VALUE (Farris, 1972) (=total homoplasy of Farris's Wagner 78 program; Klug and Farris, 1969 and Farris, 1970) is the sum of the deviation of path-length from Manhattan distances across all distinct pairs of taxa; low fractions indicate the least homoplasy. The CONSISTENCY INDEX (Kluge and Farris, 1969) is the minimum range of character-state changes in the data divided by the actual length of the tree; fractions close to unity indicate little homoplasy in a tree. The LENGTH of the tree is the sum of character-state changes -- this is also called patristic distance -- along the tree branches. The BRANCH FACTOR (Rodman et al., 1984) is the number of internal branches supported by unique synapomorphies divided by the total number of internal branches.

The determination of character polarity for the study group is discussed in detail in the Results section. Midpoint rooting was used for one analysis. Ingroup analysis was used an another analytical method.

2. Assumptions.

The following assumptions were made for this phylogenetic analysis of the Capnodiaceae.

(1) The genera utilized in this study are sister taxa.

The Capnodiaceae sensu lato embraces all of the genera distributed into several families and more than one order by Hughes (1976). Eriksson (1981) emphasized a monophyletic view with his grouping of Hughes's families into a single suborder. An alternative view is that of Barr (1979, 1983) who distributed the taxa of the Capnodiaceae sensu lato in two subclasses, three orders, and four families.

(2) The phylogeny of the teleomorphs is representative of the evolution of the family.

The capnodiaceous teleomorphs and conidiogenous fungi are often produced from similar appearing hyphal morphs. The darkly pigmented hyphal growths form a mycelial network on living plant surfaces. Several kinds of these hyphal morphs have been described (Mendoza, 1925; Hughes, 1976). The similar morphology of the hyphae subtending teleomorphic and anamorphic reproductive structures has been used as an argument for phylogentic relationships of teleomorphs and anamorphs (Hughes, 1976). Few of the capnodiaceous holomorphs submised with this method have been satisfactorily demonstrated to be comprised of the proposed teleomorphic and anamorphic states (Reynolds, 1982). I have produced an anamorph from ascospore derived cultures for Capnodium walteri (unpublished data). The developmental cycle of Scorias spongiosa closely monitored in nature allows a cautious admission of pleomorphy (Reynolds, 1979). A convincing demonstration of pleomorphy data is unavailable for other capnodiaceous species. For this reason, this phylogenetic study is done with a teleocentric focus; the pleomorphy suggested by Hughes (1976) is not considered.

sensu lato. The genera utilized as operational taxonomic units (OTU) and the major data sources are: *Capnodium* (Reynolds, 1978), *Limacinula* (Reynolds, 1971, 1975a), *Antennulariella* (Hughes, 1976), *Trichomerium* (Reynolds, 1982), *Scorias* and *Phragmocapnias* (Reynolds, 1979), *Acrogenotheca* (Hughes, 1967), *Euantennaria* (Hughes, 1974), *Trichopeltheca* (Hughes, 1965) , *Limacinia* (Reynolds, 1985a), and *Strigopodia* (Hughes, 1968).

4. Characters.

Only morphological data were available. The discussion of hazards in the choice of characters and coding by Rodman et al. (1984) is applicable. Characters were selected on the following bases: The largest number of characters was sought for which an argument of homology seemed reasonable. The characters enabled character-state coding which discriminated between genera.

Wheeler and Blackwell (1984) pointed out that conflicts in the data set are warnings that one or more characters need critical reexamination. The characters all have binary coding (Table 1).

TAXON	CHARACTER																		
character #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
ACROGENOTHECA	1	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0	0	0	1
ANTENNULARIELLA	1	0	0	0	1	0	1	0	0	0	1	0	0	0	1	1	0	0	0
CAPNODIUM	1	1	0	0	1	0	1	1	0	0	0	1	0	0	1	0	0	0	0
EUANTENNARIA	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
LIMACINIA	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
LIMACINULA	1	0	0	1	1	0	1	0	0	1	0	1	0	0	1	0	0	0	0
PHRAGMOCAPNIAS	1	1	0	0	1	0	1	0	1	0	0	1	0	0	1	0	1	1	0
SCORIAS	1	1	0	0	1	0	1	0	1	0	0	1	0	1	1	0	0	0	0
STRIGOPODIA	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
TRICHOMERIUM	1	0	1	0	1	0	1	0	1	0	0	1	0	0	1	0	1	0	0
TRICHOPELTHECA	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

TABLE 1. Character x taxon data matrix for Capnodiaceae taxa. See text under MATERIALS:characters for a discussion of the numbered characters.

The characters are defined as follows:

CHARACTER 1. Dimorphic mycelium: present 0, absent 1. This character reflects the occurence of the copious mycelium as distinctive lower and upper portions. The basal portion is in contact with the living plant surface. The hyphae of the basal portion form a network in Euantennaria, Limacinia, and Strigopodia; the hyphae of Trichopeltheca are parallel to each other. Extensions of the basal portion continue as a three-dimensional aerial network in which the ascocarps develop. The aerial network of Euantennaria and Limacinia (Fig. 1A) is more prolific than that of Strigopodia. The aerial mycelium is severely reduced to individual upraised hyphae in Trichopeltheca and the ascocarps are produced from the basal layer of parallel hyphae.

CHARACTER 2. Stalk: absent 0, present 1. The ascus-bearing portion of the ascocarp is subtended by an upright column of tissue (Fig. 2C).

CHARACTER 3. Fruit body sessile: absent 0, present 1. The fruit body develops on a mycelium formed of a reticulate network of hyphae which rests on the surface of the substratum.

CHARACTER 4. Limacinuloid: absent 0, present 1. Limacinula species have thin walled, somewhat hyaline hyphae which extend from the outer surface of the ascocarp wall into the general substratum (Reynolds, 1971). Eriksson (1981) found similarity in this habit to that of taxa in the Coccodiniaceae and Naetrocymbaceae. Hughes (1976) referred to these hyphae as occurring in a "fringe" around the ascocarp. The ascocarp illustrated in Theissen and Sydow (1917) is atypical.

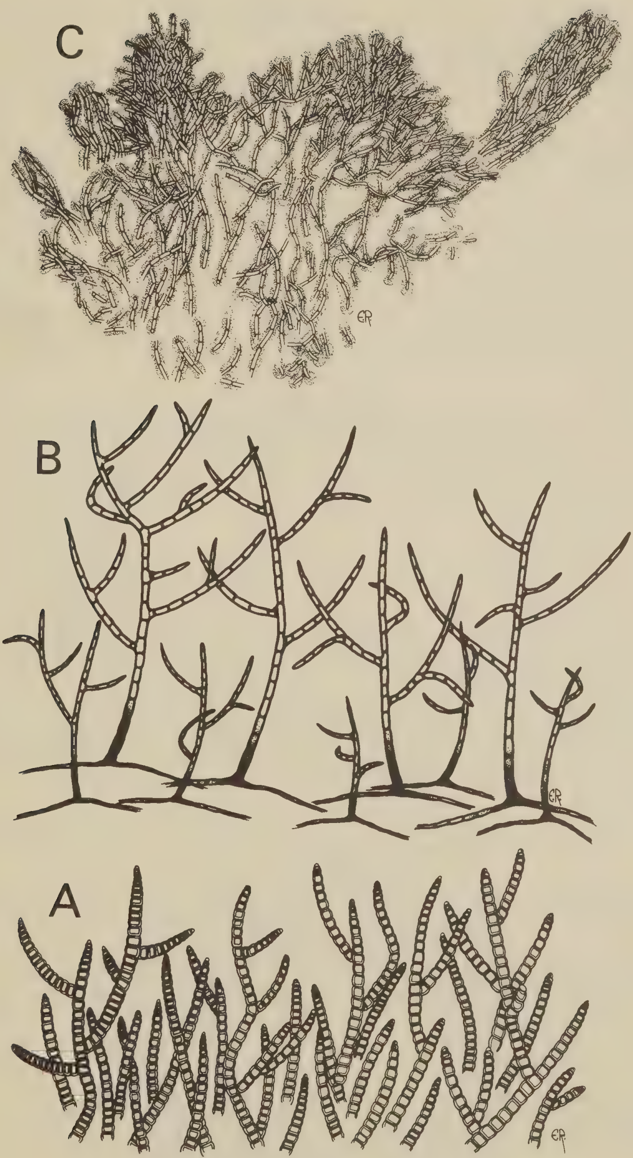
CHARACTER 5. Ascocarp wall thickness: wide 0, thin 1. The ascocarp wall of some species has a greater width than in others (Figs. 2). The thicker walls were more than 3-4 cells in depth.

CHARACTER 6. Hyphal cell shape: cylindrical 0, spherical 1. The cells comprising the hyphal strands are either cylindrical or somewhat spherical.

CHARACTER 7. Periphysoids: absent 0, present 1. Periphysoids are sterile elements in the ascocarp centrum in addition to others such as pseudoparaphyses and paraphyses (Luttrell, 1965) (Fig. 2). Eriksson (1981) questioned my report of periphysoids in Capnodium (Reynolds, 1978). I

....

Figure 1. Diagramatic representations of characters of the Capnodiaceae. A. Apical ends of the aerial portion of the dimorphic mycelium of Limacinia fernandeziana. B. Mycelium of Acrogenotheca elegans. C. Section through outer portion of stroma of Scorias spongiosa.


C
ER
B
ER
A
ER

have examined the herbarium material that he utilized for his study (kindly provided by him) as well as other collections. My opinion remains unchanged. Corlett (1970) misinterpreted the periphysoids as pseudoparaphyses (Reynolds, 1985a). This character-state datum was difficult to determine for Antennulariella and Acrogenotheca. The fruit bodies are very small and sterile elements are difficult to demonstrate if present. The lack of space in the small hymenial cavity may reflect a developmental absence of this structure, when it should be present in a phylogenetic sense. To account for both possiblities, the character was initially scored for all possible states. The PAUP algorithm accounts for this scoring by using the most parsimonious character state had it not been missing, when the tree length is computed. The taxon's location on the tree is determined in congruence with those characters without missing data. The position of the unknowns on the resultant tree assigned a coding of "1" to this character in Antennulariella and Acrogenotheca.

CHARACTER 8. Ascospore pigmented, muriform: absent 0, present 1. OTU with only pigmented muriform ascospores.

CHARACTER 9. Ascospore hyaline, traversely septate: absent 0, present 1. OTU with only hyaline traversely septate ascospores.

CHARACTER 10. Ascospore hyaline, muriform: absent 0, present 1. OTU with only hyaline muriform ascospores.

CHARACTER 11. Ascospore hyaline, one septate: absent 0, present 1. OTU with ascospores that are initially one septate in the mature ascus; later becoming multiseptate and pigmented usually after ejaculation.

CHARACTER 12. Mycelial persistence: persistent 0, deciduous 1. Mycelium persistent or deciduous. Refers do the tendency of a mycelium to persist throughout the year or to slough off at a predictable time (Reynolds, 1975b).

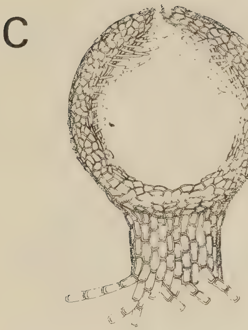
CHARACTER 13: Hyphae parallel: absent 0, present 1. Hyphae on the surface of the substrate are parallel to each other rather than reticulately disposed.

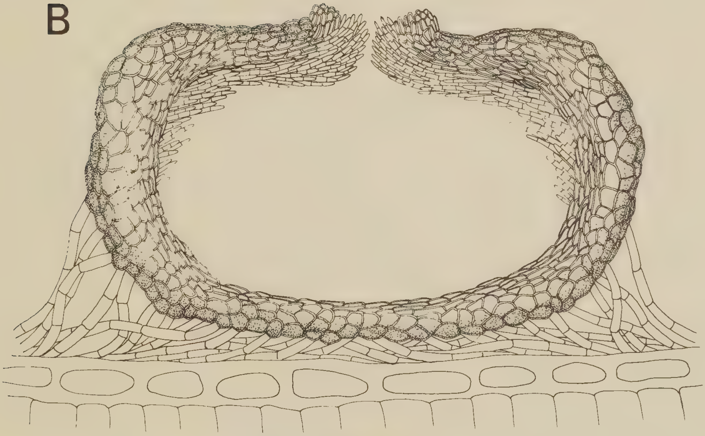
CHARACTER 14. Stroma: absent 0, present 1. The mycelium forms a stromatal structure (Reynolds, 1979) (Fig. 1C).

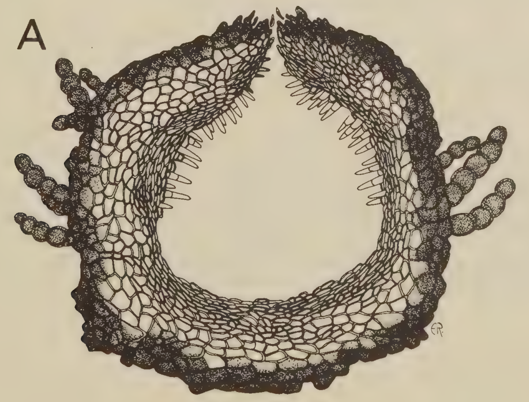
CHARACTER 15. Hyphal appendage: present 0, absent 1. The ascocarp is appendaged with hyphal strands which project from the surface of the ascocarp as though certain meristematic cells continue in a hyphal-type of growth (Figs. 2A).

……

Figure 2. Diagramatic representations of the characters of the Capnodiaceae. A. Fruit body of Limacinia fernandezana. B. Fruit body of Limacinula anomala. C. Stalked fruit body of Capnodium walterii.


C


B


A
ER

CHARACTER 16. *Antennulariella* habit: absent 0, present 1. The ascocarp is attached to the cells of the aerial hyphae from which it originated. In addition, long, cylindrical, flexuous hyphae originate from the outer ascocarp wall and mingle with the rest of the mycelium. This character is not homologous with Character 4 and Character 15.

CHARACTER 17. *Phragmocapnias* appendage: absent 0, present 1. The ascocarp is appendaged with short, acute, pigmented, often unicellular appendages.

CHARACTER 18: *Trichomerium* appendage: absent 0, present 1. The ascocarp is appendaged with elongate, stiff, usually multiseptate, pigmented setae.

CHARACTER 19. *Acrogenotheca* habit: absent 0, present 1. The mycelium in contact with the living plant surface is very reduced. The aerial hyphae from which the ascocarps originate are upright and branch at wide angles (Fig. 1B).

C. RESULTS.

1. Character compatability analysis.

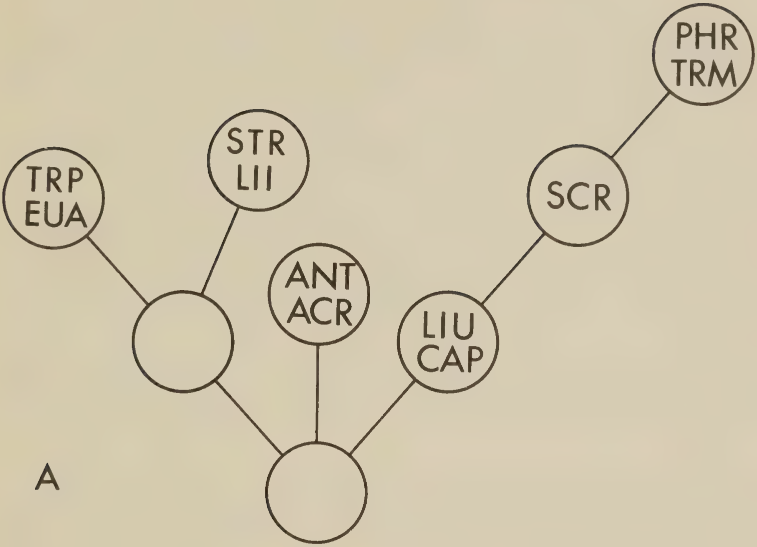
The primary analysis for character compatibility revealed two overlapping cliques (Fig. 3) which accounted for all characters. Seventeen characters (1, 3-8, and 10-19) are common to both cliques. The common group plus character 9 and 17 form a primary clique (Figs. 3A and 4). The common group plus character 2 form a smaller clique (Fig. 3B). The patterns of character distributions representing both of these cliques agree on the placement of the study group EUs (Evolutionary Unit = Operational Taxonomic Unit of the parsimony analysis). *Antennulariella* *Acrogenotheca*,

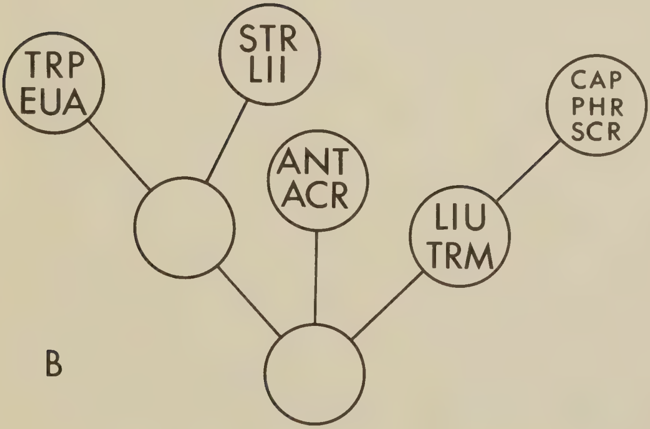
Euantennaria and *Trichopeltheca* have similar positions in both character state trees. Both trees show a branch with *Limacinula*, *Capnodium*, *Phragmocapnias*, *Scorias*, and *Trichomerium*, but in different relationships. The final estimate of evolutionary history for the Capnodiaceae sensu lato was created from the primary clique with characters 9 and 17 because of the greater compatibility, and the full resolution of the tree.

The final undirected estimate of phylogeny for the genera of the study EUs (Fig. 4) shows compatible relationships between groups of genera. This character state tree

....

Figure 3. Character compatibility analysis of the Capnodiaceae. ACR=*Acrogenotheca*; ANT=*Antennulariella*; CAP=*Capnodium*; EUA=*Euantennaria*; LII=*Limacinia*; LIU=*Limacinula*; PHR=*Phragmocapnias*; SC=*Scorias*; STR=*Strigopodia*; TRM=*Trichomerium*; TRP=*Trichopeltheca*. Seventeen characters are common to both cliques. A. The common group plus Characters 9 and 17 form a clique. B. The common group plus Character 2 form a clique.


PHR
TRM
STR
LII
TRP
EUA
SCR
ANT
ACR
LIU
CAP
A


STR
LII
TRP
EUA
CAP
PHR
SCR
ANT
ACR
LIU
TRM
B

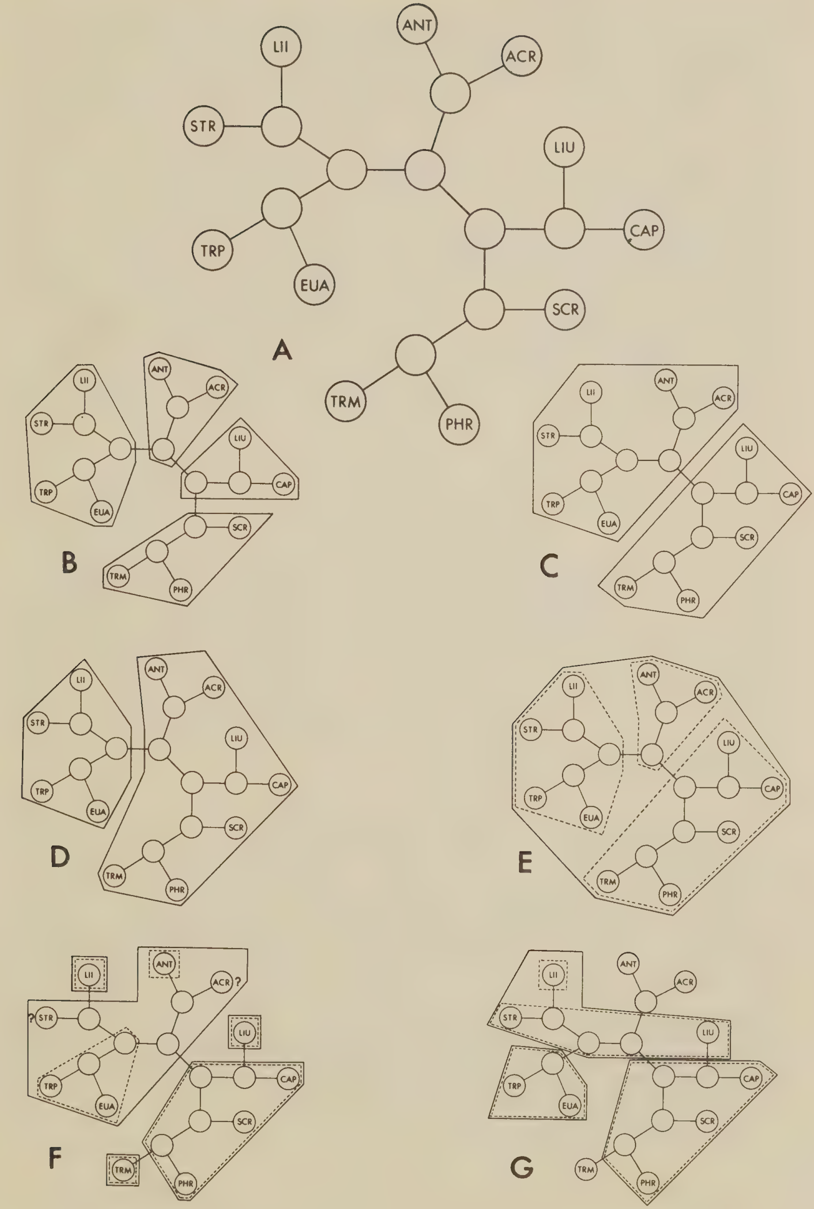
asserts that its states are convex. A comparison with the distribution of genera in the classifications which recognize a Capnodiaceae sensu stricto counter the convexity of the character state tree for the Capnodiaceae sensu lato.

The distribution of some characters on the estimate of phylogenetic history suggests evolutionary trends. Spore septation is one such trend. The septation pattern is generalized in the OTUs on one end of the trees (Fig. 4B). The ascospores of species in the Strigopodia group range from transverse to muriform. On the other end of the trees each OTU has one type of spore septation. Antennulariella and Acrogenotheca produce ascospores which have only one septum at maturity in the ascus (Character 11). The spore dispersal strategy incorporates delayed stages of hyphal initial germination and growth so that septation and pigmentation develop in steps, usually outside the ascus. Limacinula and Capnodium produce muriform ascospores which are pigmented in the latter (Characters 8 and 10). Scorias, Trichomerium, and Phragmocapnias produce ascospores with three cross septa (Character 9).

Mycelial persistence is a character of five genera on one end of the tree and deciduous mycelium is produced by the genera on the other end (Character 12). The thickness of the ascocarp wall shows a correlated trend (Character 5).

……

Figure 4. Phylogenetic estimate of the Capnodiaceae and distributions of characters and classifications using character compatibility analysis. Abbreviations for the families are given in Fig. 3A. The final undirected estimate of phylogeny for the genera of the Capnodiaceae. B. Distribution of spore septation types; general septation; one septate (Character 11); muriform septation (Characters 8, 10); traversely septate (Character 9). C. Distribution of deciduous vs. persistent types (Character 12). D. Distribution of several congruent characters: Dimorphic hyphae (Character 1); Ascocarp wall thickness (Character 5); Hyphal appendage on ascocarp (Character 15). E-G. Distribution of taxa in proposed classifications. Solid and broken lines indicate taxon broundaries; ?=taxon incertis cedis. OTUs outside taxon boundaries were not considered in classification. E. Distribution of taxa proposed in this study. Three subfamilies are contained in a single family. F. Distribution of Hughes taxa. Six families are distributed in two classes and several orders. G. Distribution of Barr's taxa. Four families are distributed in two suborders and three orders. The Operational Taxonomic Units (=EUs of the character state tree) in the unrooted trees appear as two patristically equidistant clades in relationship to the midpoint. OTU pairs Euantennaria and Trichopeltheca, Limacinia and Strigopodia, and Acrogenotheca and Antennulariella form one group and Limacimula, Capnodium, Scorias, Phragmocapnias and Trichomerium form the other group.


LII
STR
TRP
EUA
ANT
ACR
LIU
CAP
SCR
TRM
PHR
A
B
C
D
E
F
?
?
G

2. Parsimony analysis.

Parsimony analysis was carried out using midpoint rooting. The tree is rooted at the midpoint of the longest path connecting any pair of taxa with this method. The resultant unrooted trees are represented in Figs. 5A and 6A-D. The statistics for the trees were Length= 20.0, Consistency Index= 0.95, f-Value= 14, and Branch Factor= 0.875.

The three midrooted tree generated by PAUP differ in the topology of only one of the equidistant clades. The relationships of *Antennulariella*, *Euantennaria*, *Limacinia*, and *Strigopodia are represented in* Fig. 6A-C. *Euantennaria* and *Trichopeltheca* are sister taxa in all *three configurations and are subtended* by the node with character state HTU-1 (Table 2). The three versions result from their forming a sister pair to *Strigopodia* (Fig. 6A), to *Limacinia* (Fig. 6B), and to *the sister* pair *Strigopodia and Limacinia* (Fig. 6C); the character state *of subtending nodes are H*UT-2 in all three cases. Character 2 is the only homoplastic character. A reversal occurs in the branch clade terminated by *Trichomerium*.

3. Character polarity and tree rooting.

Proposals for estimating evolutionary character polarity include outgroup analysis, ingroup analysis, the ontogenetic method, and the paleontological method (Stuessy and Crisi, 1984). Donoghue and Cantino (1984) state that outgroup analysis has found most acceptance among practitioners of parsimony analysis. They note the difficulty of the use of outgroup analysis in angiosperm groups due to a lack of well-corroborated hypotheses of cladistic relationships among higher taxa. Cryptogams such as fungi are no exception to this observation. Agreement is lacking concerning the ancestor of the bitunicate ascomycetes as well as the sequence of descendants within the bitunicate ascomycete. More specificially given the study group used here as the Capnodiaceae sensu lato, what are the monophyletic subgroups?

Eriksson (1981) proposed a phylogenetic sequence for the evolution of the bitunicate ascomycetes; i.e. primitive unitunicate ascus with thickened upper end which had a pore, ascus with rostrum-type of endotunica and a ring, semifissitunicate ascus with the extension of the endotunica but without separation of the two tunica. The fissitunicate ascus and the unitunicate asci were derived from this point. Hawksworth (1982) suggested that several modifications of the semifissitunicate ascus independently led to modern groups, i.e. the bitunicate ascus would have evolved with the modification of the endotunica; the Xylariaceae and Helotiales were derived by a loss of the ectotunica; the Lecanorales lichenized ascomycetes arose with a loss of the endoascus ability to extend during spore ejaculation and the gain of an apical ring.

The fossil record of fungi (Tiffney and Barghoorn, 1974) shows evidence that the fissitunicate ascus coevolved with the angiosperm leaf. Eriksson's (1981) "clades" 80 - 92 consist mostly of fungi that occur only on living leaves (Hansford, 1946), including the taxa included in the Capnodiaceae sensu lato.

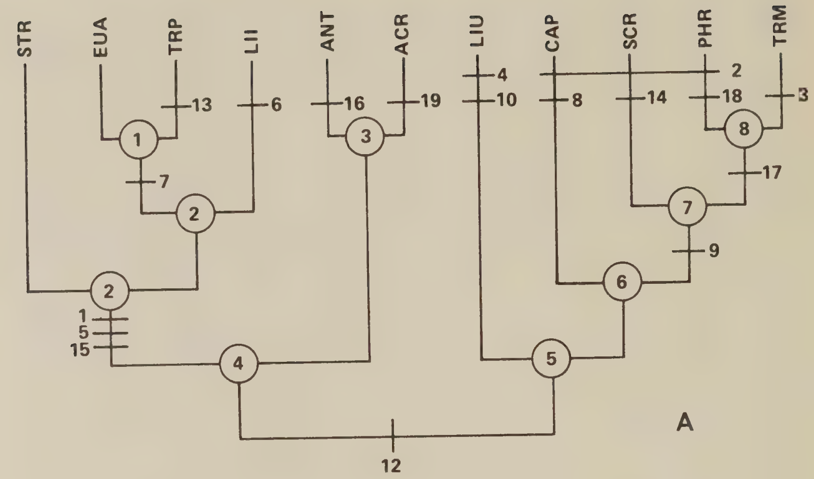
Aside from the general question of the ancestor of bitunicate ascomycetes, the descent of specific loculoascomycetes is unresolved. Barr (1979) stated that the Leptopeltidaceae was the ancestor of both unitunicate and bitunicate ascomycetes. This reasoning implies that part of the unitunicate ascomycetes evolved from an ancestor common to the bitunicates. Eriksson (1981) lists the unitunicate fungi before the bitunicate ascomycetes implying that all unitunicate ascomycetes are ancestral to bitunicate species. Eriksson believed the ascus in the Erysyphaceae and the Meliolaceae to be bitunicate, while Barr indicates an ancestral position for these fungi in the unitunicate ascomycetes. Barr accepted the conclusions of Holm and Holm (1977) that the Leptopeltidiaceae ascus is unitunicate. Hughes (1976) considered the ascus of the Capnodiaceae genus Trichomerium (Reynolds, 1982) to be unitunicate because of the modification of the endotunica. Eriksson (1981) considered this same character merely a variation of the bitunicate ascus wall.

The origin of particular unitunicate ascus groups by simplification of the fissitunicate ascus is suggested by several studies. Minter and Cannon (1984) found both unitunicate and functionally bitunicate species occurring in the same family. "It just happens that the Rhytismataceae is a natural family which is rather variable in ascus opening mechanisms. That variability is likely to provide valuable insights into the relation between individual genera within the family, but it should not be used to scatter the members of this family throughout the ascomycetes." (I strongly disagree with the inclusion of two diverse ascus types in the same family.)

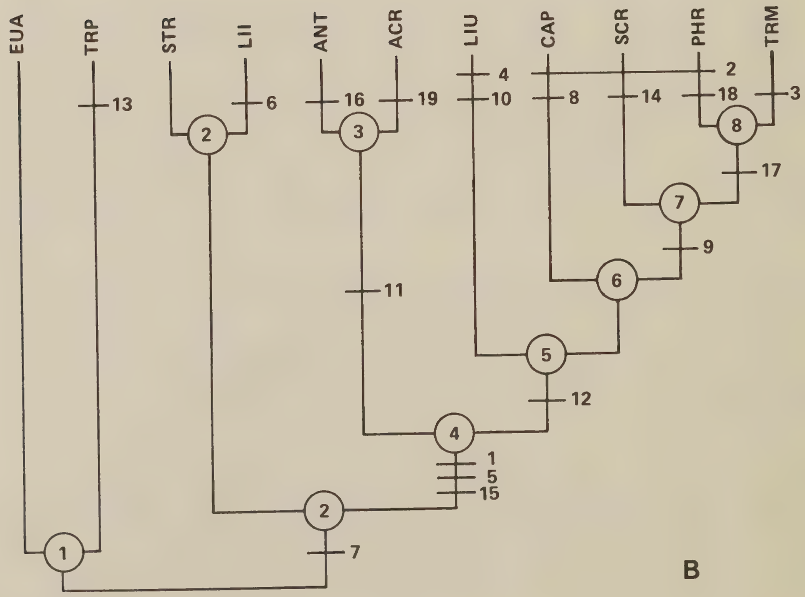
Crisci and Stussey, 1980) and Stevens (1980) provide similar guidelines for determining evolutionary directionality. Criteria were grouped as independent or first-level and dependent or second-level. The dependent criteria of Stevens differ from the first-level criteria of Crisci and Stussey in Stevens's rejection of ingroup analysis. Under the circumstances, this seems to be the best way to hypothesize polarity of capnodiaceous characters.

....

Figure 5. Most parsimonious trees for the Capnodiaceae. Family name abbreviations are listed in Fig. 2. The position of synapomorphies are indicated by Character number (Table 1) in the internal and terminal branches. The HTUs (Table 2) are shown at the nodes. A. Midrooted tree. B. Tree rooted with the sister pair Euantennaria and Trichopeltheca as the designated ancestors.


STR
EUA
TRP
LII
ANT
ACR
LIU
CAP
SCR
PHR
TRM

A


EUA
TRP
STR
LII
ANT
ACR
LIU
CAP
SCR
PHR
TRM

B

One of the independent or first level criteria is the character state distribution or "common is primitive". A hypothetical ancestor can be based on the highest ratio of "0" to "1" coding for each of the OTUs (Table 1) and optimized HTUs (Table 2). The ratios of "0"/"1" in the present study group vary from 19/0 for *Strigopodia* to 10/9 for *Phragmocapnias* (Table 1). Thus, the most common "0" state can be taken as primitive. *Strigopodia* would be the OTU used for character polarization.

This method of rooting is similar to the Lundberg (1972) method of outgroup selection. The PAUP program carried out Lundberg rooting by first seeking the shortest unrooted tree for the ingroup taxa. The resulting tree is then rooted at the position in which a hypothesized ancestor containing plesiomorphic states for all characters would be attached to the tree (Swofford, 1984) -- the "outgroup node" of Maddison et al. (1984). HTU-1 corresponds to the Lundberg node (=*Strigopodia*) for this study group (Table 2).

character #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
HTU-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HTU-2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
HTU-3	1	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0	0	0	0
HTU-4	1	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0
HTU-5	1	0	0	0	1	0	1	0	0	0	0	1	0	0	1	0	0	0	0
HTU-6	1	1	0	0	1	0	1	0	0	0	0	1	0	0	1	0	0	0	0
HTU-7	1	1	0	0	1	0	1	0	1	0	0	1	0	0	1	0	0	0	0
HTU-8	1	1	0	0	1	0	1	0	1	0	0	1	0	0	1	0	1	0	0

TABLE 2. Character x Hypothetical Taxonomic Unit data matrix for Capnodiaceae taxa. See text under MATERIALS characters for a discussion of the numbered characters.

Ontogenetic states is another first level or independent indicator of the direction of character state convexity. The trend represented by ascospore ontogeny is represented in Fig. 4B. Spore ontogeny progresses from a variety of septation states in the species of a single genus to a single type of septation being characteristic of all species in a taxon. The transseptate to muriform ascospores in the species of *Euantennaria* and *Strigopodia* might be interpreted to represent arrested stages of spore development. The maturing spore is first divided into two cells, then more transsepta and longisepta form and the cell might elongate. The derived genera produce spores representing a single stage in this developmental sequence; *Antennulariella* -- two celled at maturity in the ascus, becoming more developed after dispersal; *Scorias* -- three transsepta; and *Limacinula* muriform spores. A major point is that these genera are also distinguished by more than this one synapomorphy. This concept of spore ontogeny was the basis of combining Ophiocapnocoma with Limacinia (Reynolds, 1985).

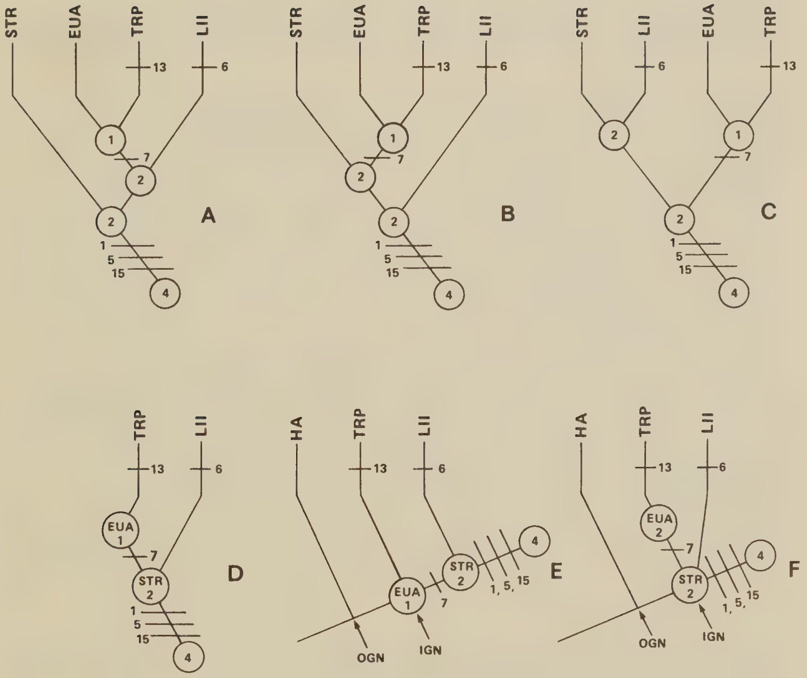
A second-level or dependent criterion is group trends in these taxa. The mycelium habit shows major changes which I believe represent evolutionary progression in the leaf surface microhabitat. The OTUs of the EUA-TRP-STR-LII branch of the phylogenetic tree (Fig. 4A) produce the fruit body upon or within the hyphae of a loosely woven thickened mycelial mat which forms basal and aerial portions. The mycelium becomes specialized in the ANT-ACR branch (Fig. 4A). The mycelium is primarily a network of surface hyphae in the LIU-CAP-SCR-PHR-TRM branch (Fig. 3).

Meacham and Estabrook (1985) point out that characters that are related to each other functionally, developmentally, or morphologically will have a dependent compatibility. Evolutionary trends would act on suites of these characters because of this dependency. One suite of characters might be attributed to the distribution in a tropical or temperate climate. Persistent mycelium and pigmented ascospores seem characteristic of temperate climate species. Deciduous mycelium and hyaline spores seem characteristic of tropical climate species. A transition from one type of environment to the other might explain the change of spore strategy from a genus with variable septation to a genus with a single spore septation type and the change from persistent and temperate to deciduous and tropical habit.

Evolutionary pressure might be attributed to the positioning of the ascocarp for the most beneficial spore dispersal from the fissitunicate ascus. Only Scorias produces glabrous ascocarps; yet the ascocarps are elevated by stalks which are subtended by a dense mycelial mat. The genera produced in the aerial portion of a looser mycelial mat, such as Limacinia and Euantennaria are in a sense intercalary. The appendages are hyphal outgrowths. Antennulariella is usually found among the aerial mycelium of other capnodiaceous species; the appendages are specialized hyphal outgrowths, differing in morphology from the generative hyphae (Character 16). The ascocarps of Limacinula produce a somewhat similar growth, but in a different habitat (Character 4). Stalks subtend the ascocarps of Capnodium and Phragmocapnias (Character 2) to elevate them from the substratum.

....

Figure 6. Analysis of Cladogram. Abbreviations for the family names are given in Fig. 3. A-C. Three configurations of the midrooted tree (Fig. 5). OTUs and HTUs are indicated as explained in Fig. 5. D. The plesions Euantennaria and Strigopodia are compressed into the node with an identical character state. E-F. Tree represented by clade in D with designated root. OGN=Outgroup Node; IGN=Ingroup Node. E. Tree rooted with plesion Strigopodia at IGN. F. Tree rooted with plesion Euantennaria at IGN.


STR
EUA
TRP
LII
13
6
1
7
2
2
1
5
15
4
A
STR
EUA
TRP
LII
13
6
1
7
2
2
1
5
15
4
B
STR
LII
EUA
TRP
6
13
2
1
7
2
1
5
15
4
C
TRP
LII
13
6
EUA 1
7
STR 2
1
5
15
4
D
HA
TRP
LII
13
6
STR 2
4
1, 5, 15
EUA 1
7
OGN
IGN
E
HA
TRP
LII
13
6
EUA 2
7
STR 2
4
1, 5, 15
OGN
IGN
F

Two roots are suggested using these methods of determining character polarity. The OTU and HTU character state with the commonest distribution, all "0", is that of *Euantennaria* and of HTU-1. Thus a hypothetical ancestor would be coded with "0" for all nineteen characters in the data matrix of this study group. The use of *Euantennaria* and its sister taxon, *Trichopeltheca*, for character polarization is in agreement with the position assigned these genera to a terminal end of the unrooted tree; the tree produced by the character compability analysis shows similar positions. The tree rooted in this manner shows Character 7 as a plesiomorphy on the main stem. An alternative root would be the sister taxa *Strigopodia* and *Limacinia*. These two OTUs are positioned in the same end of trees generated by both analyses. The tree rooted in this manner shows Character 7 as an apomorphy on a clade terminated by *Euantennaria* and *Trichopeltheca*, rather than the main stem.

Further support for a choice of an ingroup taxon for characterization polarization is derived from consideration of the plesion nature of *Euantennaria* and *Strigopodia*. The character state of *Euantennaria* is the same as HTU-1 (Tables 1 and 2). The character state of *Strigopodia* and HTU-2 are the same. Thus, if the OTU is "suppressed" to the node with the same character state, it assumes the position of an ancestor. The unrooted trees bearing *Strigopodia* and *Euantennaria* then become identical (Fig. 6D). *Euantennaria* is seen as the ancestoral taxon to *Trichopeltheca*; *Strigopodia* is ancestral to *Euantennaria* and to *Limacinia*.

Rooting with the plesion *Strigopodia* (Fig. 6E) as the Ingroup Node (Maddison et al., 1984) produces an unresolved tree. A tricotomy results from *Euantennaria* and *Limacinia*. Furthermore, *Trichopeltheca* is shown as a monocotomy. Rooting with the plesion *Euantennaria* as the Ingroup Node (Fig. 6F) produces a resolved tree. *Trichopeltheca* is descended from *Euantennaria* at the Ingroup Node distinguished by autapomorphy Character 13.

Strigopodia is descended from *Euantennaria* with the change in Character 7; *Limacinia* is descended from *Strigopodia* and is distinguished by the autapomorphy Character 6.

D. CONCLUSIONS.

The trees produced in this study support the hypothesis that the Capnodiaceae sensu lato is monophyletic. Several subclades, recognized proposed here as subfamilies, generally correspond to taxa proposed by others. Congruence with the Barr and Hughes classifications is achieved with the recognition of the phylogenetic relatedness of the study group, rather than scattering the genera through several suprafamilial taxa. The scheme for Ascomycetes proposed by Eriksson (1982) is the acceptable ordinal framework for the classification.

I recognize the following taxonomic treatment of the Capnodiaceae.

Subclass Euascomycetidae
Group Ascoloculares
Order Dothideales
Suborder Capnodioideae

FAMILY Capnodiaceae (Saccardo) Hohnel, pro parte, teleomorphoses only.
Hohnel (1910); Spegazzini (1918), Theissen and Sydow (1917), Arnaud (1911), Batista and Ciferri (1963), Hughes (1976), Reynolds, (1978); Eriksson (1981).

Basionym=subfamily Capnodiaceae Saccardo
Saccardo (1880)
=Antennulariellaceae Woronochin, pro parte, teleomorphoses only. Woronochin (1925); Hughes (1976).
=Euantennariaceae Hughes & Corlett *in* Hughes, pro parte, teleomorphoses only. Hughes (1972); Hughes (1976).
=Metacapnodiaceae Hughes & Corlett *in* Hughes, pro parte, teleomorphoses only. Hughes (1972); Hughes (1976).
=Triposporiopsidaceae Hughes, pro parte, teleomorphoses only. Hughes (1976).

SUBFAMILY Capnodioideae Saccardo
Saccardo (1882)

Type genus= *Capnodium* Montagne: Montagne (1849); Reynolds, (1978).

This provisionally recognized established subfamily includes the following genera:

Limacinula (Saccardo) Hohnel: Hohnel (1909); Reynolds (1971).

Phragmocapnias Theissen & Sydow: Theissen and Sydow (1917); Reynolds (1978).

Scorias Fries: Fries (1825); Reynolds (1979).

Trichomerium Spegazzini: Spegazzini (1918); Reynolds (1982).

SUBFAMILY Limacinioideae subfamily novo prov.

Type genus= *Limacinia* Neger *in* Johow: Johow (1896); Reynolds (1985).

This provisional subfamily also includes the following genera:

Euantennaria Spegazzini, pro parte, teleomorphosis only; Spezazzini (1918); Hughes (1975, 1976).

Strigopodia Batista in Batista, Maia, & Vital, pro parte, teleomorphosis only: Batista, Maia and Vital (1957); Hughes (1968).

Trichopeltheca Batista, Costa & Ciferri, pro parte, teleomorphosis only: Batista, Costa and Ciferri (1957); Hughes (1965), Corlett (1970), Corlett et al. (1973).

SUBFAMILY Antennularielloideae subfamily novo prov.

Type genus= Antennulariella Woronochin, pro parte, telemorphoses only: Woronochin (1915); Hughes (1976).

This provisional subfamily also includes the following genus:

Acrogenotheca Ciferri & Batista in Batista & Ciferri, pro parte, telemorphoses only: Batista and Ciferri (1963); Hughes (1967, 1976)

=Brooksia Hansford, pro parte, teleomorphosis only: Hansford, 1956; Deighton & Pirozynski, 1966).

Cooke and Hawksworth (1970) assumed that Hohnel (1910) referred to Saccardo (1882) when they recognized the Capnodiaceae (Sacc.) Hohnel with the basionym as the Saccardo subfamily Capnodiaceae in his Fragmente zur Mykologie 532 entitled, "Ubersich der Capnodiaceen-gatungen"; later reference was made to the Capnodiacee (Hohnel, 1911). The authorship by F. von Hohnel was recognized by Hughes (1976) as per Cooke and Hawksworth (1970), and by Barr (1979). Arx and Muller only used Hohnel with no reference to Saccardo. Eriksson (1981, 1982) attributed the family name to Theissen and Sydow (1917); these authors recognize Hohnel (1910) as the author of Capnodiaceae and give reference to Saccardo (1910).

The ideal way to compare the results of this study with other phylogenetic hypotheses to compare representative trees. The classifications of Hughes and Barr provide hypotheses for comparative purposes. Devising a tree to represent these views requires the construction of tree topologies to representing their implied phylogenetic hypothesis. Another approach is to impose the classification of these authors on the trees produced in this study.

The character state tree for Hughes's (1976) four family classification in represented in Fig. 4F. The polyphyly is created by suprafamilial gerrymandering. Limacinia was assigned to the order Pleosporales (Corlett et al. 1973). *Limacinula* was suggested as a member of the order Chaetothyriales. *Trichomerium* was said to have a unitunicate ascus and therefore in a different subclass. The convexity is restored by ignoring these peccadillos by bringing *Limacinia*, *Limacinula*, and *Trichomerium* into more direct lines of descent with other capnodiaceous taxa.

The character state tree for Barr's (1979) classification of the study EUs as they would appear in the orders of the Loculoascomycetes is represented in Fig. 4G. *Antennulariella*, *Acrogenotheca* and *Trichomerium* were not mentioned. The remaining capnodiaceous genera are seperated from each other by grouping with other taxa in three orders and four families. Gross polyphyly is thus introduced into the evolutionary history of capnodiaceous genera with the filial distance imposed by Barr's phylogenetic hypothesis.

The clades of the rooted tree from the parsimony analysis can be compared with the classification proposed by Hughes (1976). His Euantennariaceae corresponds to the most ancestral clade with the sister taxa *Euantennaria* and *Trichopeltheca*. The Metacapnodiaceae, containing the genus *Limacinia* (fide Reynolds, 1985a) is a clade; *Strigopodia*, a taxon of uncertain affinity in the Hughes system, is a sister taxon. *Antennulariella*, the taxon in Hughes's Antennulariellaceae, and a sister taxon, *Acrogenotheca* are the terminal taxa of a clade. *Limacinula* was of uncertain affinity; it the terminal taxon of a branch. The three sequential taxa, *Capnodium*, *Scorias*, and *Phragmocapnias* were placed in the Capnodiaceae sensu stricto by Hughes. The last taxon on the tree depicted in Fig. 4F, *Trichomerium*, was said by Hughes to produce a unitunicate ascus and was banished from the loculoascomycetes on this basis.

The data from the parsimony analysis are uncorrelated with the Barr (1979, 1983) classification. The nine OTUs of this study to be found in her keys were distributed by her in two subclasses, three orders, and four families. *Euantennaria* and *Trichopeltheca* would be assigned to the Subclass Loculoparenchymatomycetidae, Order Dothideales, Family Euantennariaceae. The subclass Loculoedaphomycetidae would contain *Limacinia* (fide Reynolds 1985a) of the Family Metacapnodiaceae and *Strigopodia* and *Limacinula* of the Family Naetrocymbaceae of the Order Chaetothyriales. *Capnodium*, *Scorias*, and *Phragmocapnias* were placed in the Order Asterinales, Capnodiaceae (sensu stricto).

The Capnodiaceae recognized here can serve as the outgroup in the universally parsimonious construction of the phylogeny of other loculoascomycete groups. Maddison et al. (1984) note in their discussion of outgroup analysis and parsimony that parsimony in the outgroups is highly desirable. Accordingly, the capnodiaceous might be used as an outgroup for analyses that examining relationships within the Chaetothyriaceae Hansford ex Barr (1979) and the Herpotrichiellaceae Munk (1957).

VI. BIBLIOGRAPHY.

ARNAUD, G. 1911. Contribution à l'étude des fumagines. 2: Systematique et organization des espèces. Ann. École Natl. Agric. Montpellier, sér. 2, 10:211-330. ARX, J. A. von, and E. MÜLLER. 1975. A re-evaluation of the bitunicate ascomycetes with keys to families and genera. Centraalbureau v. Schimmelcultures Baarn, Studies in mycology 9:1-159. BARR, M. E. 1979. A classification of loculoascomycetes. Mycologia 71:935-957. BARR, M. E. 1983. The ascomycete connection. Mycologia 75:1-13. BATISTA, A. C. AND R. CIFERRI. 1963. Capnodiales. Saccardoa 2:1-296. BATISTA, A. C., A. COSTA, AND R. CIFERRI. 1957. Organogenese e systematica dos fungos Trichopeltinacee (Theiss.) emend. nobis. Publ. Inst. Micol. Recife 90:1-24. BATISTA, A. C., H. S. MAIA, AND A. F. VITAL. 1957. Estudos Pernambucoanos sobre fungos Parodiosidaceae. Anais So. Biol. Pernambuco 15:429-443. BERKELEY, M. A. AND J. B. H. J. DESMAZIERES. 1849. On some moulds referred by authors to Fumago, and on certain allied or analogous forms. J. Roy. Hort. Soc. London. 4:244-260. BOISE, J. M. 1985. A traditional fungal taxonomist tries cladistics. Mycological Newsletter 36:19. CHURCHILL, S. P. 1984. A phylogenetic analysis, classification and synopsis of the genera of the Grimmiaceae (Musci). pp. 127-144. in V. A. Funk and D. R. Brooks, Advances in Cladistics. Proceedings of the first meeting of the Willi Hennig Society. The New York Botanical Garden. New York. CHURCHILL, S., E. O. WILEY AND L. A. HAUSER. 1985. A critique of Wagner groundplan-divergence studies and a comparison with other methods of phylogenetic analysis. Taxon 33:212-232. Cooke, W. B. and Hawksworth, D. L. 1970. A preliminary list of the families proposed for fungi. Mycol. Pap. 121:1-86. CORLETT, M. 1970. Ascocarp development of two species of sooty molds. Can. J. Bot. 48:991-995. CORLETT, M., S. J. HUGHES, AND M. KAUFERT. 1973. New Zealand fungi 19. Centrum organization in some Euantennariaceae and Metacapnodiaceae. N. Zealand J. Bot. 11:213-230. CRISCI, J. V. AND T. F. STUESSY. 1980. Determining primitive character states for phylogenetic reconstruction. Syst. Bot. 5:112-135. CURRAH, R. 1984. Phylogenetic reconstruction in the keratinolytic families of the Onygenales (Ascomycetes). AIBS 35th Annual meeting program. Fort Collins, Colorado. DEIGHTON, F. C. AND K. A. PIROZYNSKI. Microfungi. II. Brooksia and Grallomyces; Acrogentheca ornata sp. nov.: The genus Xenosporium. Mycol. Pap. 105:1-35. DONOGHUE, M. J. AND P. D. CANTINO. 1984. The logic and limitations of the outgroup substitution approach to cladistic analysis. Syst. Bot. 9:192-202. DUNCAN, T. 1980. Cladistics for the practicing taxonomist -- an eclectic view. Syst. Bot. 5:136-148. DUNCAN, T. 1984. Willi Hennig, character compatibility, Wagner Parsimony, and the "Dengrogrammaceae" revisted. Taxon 33:698-704. DUNCAN,

T. 1986. Semantic fencing: A final riposte with a Hennigian crutch. Taxon 35:110-117. DUNCAN, T. and T. F. STUESSY. 1984. Cladistics: perspectives on the reconstruction of evolutionary history. Columbia University Press. New York. ELDREDGE, E. and J. CRACRAFT. 1980. Phylogenetic patterns and the evolutionary process. Method and theory in comparative biology. Columbia University Press. New York. ELLIS, J. B. AND B. M. EVERHART. 1892. The North American Pyrenomycetes. Privately published. ERIKSSON, O. 1981. The families of bitunicate ascomycetes. Opera Botanica 60:1-220. ERIKSSON, O. 1982. Outline of the ascomycetes -- 1982. Mycotaxon 15:203-248. FARRIS, J. S. 1970. Methods for computing Wagner trees. Syst. Zool. 19:83-92. FARRIS, J. S. 1972. Estimating phylogenetic trees from distance matrices. Amer. Naturalist 106:645-668. FARRIS, J. S. AND A. G. KLUGE. 1985. Parsimony, synapomorphy, and explanatory power: A reply to Ducan. Taxon 34:130-135. FARRIS, J. S. AND A. G. KLUGE. 1986. Synapomorphy, parsimony, and evidence. Taxon 35:298-305. FRIES, E. M. 1825. Systema orbis vegetabilis. Pars 1. I-VII + 1-373. FUNK, V. A. 1984. Special concerns in estimating plant phylogenies. pp. 73-86. in V. A. Funk and D. R. Brooks. Advances in cladistics. Proceedings of the first meeting of the Willi Hennig Society. New York Botanical Garden. New York. HANSFORD, C. G. 1946. The foliicolous ascomycetes, their parasites and associated fungi, especially as illustrated by Uganda specimens. Mycol. Pap. 15:1-240. HAWKSWORTH, D. L. 1982. Co-evolution and the detection of ancestry in lichens. Jour. Hattori Bot. Lab. 52:323-329. HÖHNEL, F. VON. 1909. Fragmente zur Mykologie. VIII. Mitteilung, No.354-406. Sitzungsber. Kaiserl. Akad. Wiss., Math.-Naturwiss. Cl., Abt. 1. 118:1157-1246, plates 1 & 2. HÖHNEL, F. von. 1910. Fragmente zur Mykologie. XII. Mitteilung, No. 574-641. Sitzungsber. Kaiserl. Akad. Wiss., Math.-Naturwiss. Cl., Abt. 1. 119:877-958. HÖHNEL, F. von. 1911. Fragmente zur Mykologie XIII. Mitteilung, No. 642-718. Sitzungsber. Kaiserl. Akad. Wiss., Math.-Naturwiss. Cl., Abt. 1. 120:379-484. HØILAND, K. 1983. Cortinarius subgenus Dermocybe. Opera Botanica 71:1-112. HOLM, K. AND L. HOLM. 1977. Nordic junipericolous ascomycetes. Symb. Bot. Upsala 21:1-70. HOOG, G. S. de. 1979. Deductive classification -- worked examples using anamorph and teleomorph data in the ascomycetes. pp. 215-239. in B. Kendrick. The whole fungus. National Museums of Canada. Ottawa. HUGHES, S. J. 1965. New Zealand fungi 5. Trichothallus and Plokamidomyces states of Trichopeltheca. New Zealand J. Bot. 3:320-332. HUGHES, S. J. 1967. New Zealand fungi 10. Acrogenotheca elegans. New Zealand J. Bot. 5:504-518. HUGHES, S. J. 1968. Strigopodia. Canadian J. Bot. 46:1099-1107. HUGHES, S. J. 1972. New Zealand fungi 17. Pleomorphism in Euantennariaceae and Metacapnodiaceae, two new families of sooty moulds. New Zealand J. Bot. 10:225-242. HUGHES, S. J. 1974. Euantennaria with Antennatula and Hormisciella states. New Zealand J. Bot. 12:299-356. HUGHES, S. J. 1976. Sooty moulds. Mycologia 68:693-820. JOHOW, F.

1896. Estudios sobre la flora de las islas de Juan Fernandez. Cevantes, Santiago de Chile. KLUG, A. G. and J. S. FARRIS. 1969. Quantitative phyletics and the evolution of anurans. Syst. Zool. 18:1-32. LUNDBERG, J. G. 1972. Wagner networks and ancestors. Syst. Zool. 18:1-32. LUTTRELL, E. S. 1965. Paraphysoids, pseudoparaphyses, and apical paraphyses. Trans. Brit. Mycol. Soc. 48:135-144. LUTTRELL, E. S. 1973. Loculoascomycetes. pp. 135-219 in G. C. Ainsworth, F. K. Sparrow and A. S. Sussman (editors). The fungi IV A. Academic Press, New York. MADISON, W. P., M. J. DONOGHUE, AND R. MADISON. 1984. Outgroup analysis and parsimony. Syst. Zool. 33:83-103. MEACHAM, C. A. 1980. Phylogeny of the Berberidaceae with an evaluation of classifications. Syst. Bot. 5:149-172. MEACHAM, C. A. 1981. A probability measure for character compatibility. Math. Biosci. 57:1-18. MEACHAM, C. A. AND G. F. ESTABROOK. 1985. Compatibility methods in systematics. Ann. Rev. Ecol. Syst. 16:431-446. MENDOZA, J. M. 1925. Capnodiaceae, p. 52-63. in F. L. Stevens, Hawai'ian fungi. Bernice P. Bishop Museum Bull. 19. MINTER, D. W. AND P. F. CANNON. 1984. Ascospore discharge in some members of the Rhytismataceae. Trans. British Mycol. Soc. 83:65-92. MONTAGNE, M. 1849. De Capnodio, nov. gen. Ann. Sci. Nat. Bot. Ser. 3, 12:233-234. MUNK, A. 1957. Danish pyrenomycetes. Danish Bot. Ark. 17:1-491. REYNOLDS, D. R. 1971. The sooty mold ascomycete genus Limacinula. Mycologia 63:1173-1209. REYNOLDS, D. R. 1975a. The centrum of the sooty mold ascomycete Limacinula samoensis. Amer. J. Bot. 62:775-779. REYNOLDS, D. R. 1975b. Observations on growth forms of sooty mold fungi. Nova Hedwigia 26:179-193. REYNOLDS, D. R. 1978. Foliicolous ascomycetes. 2. Capnodium salicinum Montagne emend. Mycotaxon 7:501-507. REYNOLDS, D. R. 1979. Foliicolous ascomycetes. 3. The stipitate capnodiaceous species. Mycotaxon 8:417-445. REYNOLDS, D. R. 1982. Foliicolous ascomycetes. 4. The capnodiaceous genus Trichomerium. Mycotaxon 14:198-220. REYNOLDS, D. R. 1985a. Foliicolous ascomycetes 6. The capnodiaceous genus Limacinia. Mycotaxon 23:153-168. REYNOLDS, D. R. 1985b. A phylogenetic view of the Capnodiaceae sensu lato. Mycological Newsletter 36:37. REYNOLDS, D. R. 1986. Proving the anamorphic connection. pp.157-180 in J. Sugiyama (editor), Pleomorphic fungi: The diversity and its taxonomic implications. Kodansha, Ltd/Elsvier, Tokyo. RODMAN, J. E., M. K. OLIVER, R. R. NAKAMURA, J. U. MCCLAMMER Jr., AND A. H. BLEDSOE. 1984. A taxonomic analysis and revised classification of Centrospermae. Syst. Bot. 9:297-323. SACCARDO, P. A. 1882. Sylloge fungorum omnium hucusque cognitorum. Vol. 1. Pyrenomycetes. pp. 73-80. Typus Seminarii, Patarii. SPEGAZZINI, C. 1918. Notas Micologicas. Physis (Buenos Aires) 4:281-295. STEVENS, P. F. 1980. Evolutionary polarity of character states. Ann. Rev. Ecol. Syst. 11:333-358. STUESSY, T. F. AND J. V. CRISCI. 1984. Problems in the determination of evolutionary directionality of character state change for phylogenetic reconstruction. pp. 71-87. in T. Duncan and T. F. Stuessy (editors). Cladistics: Perspectives on the reconstruction of evolutionary history. Columbia University Press. New York. SWOFFORD, D. L. 1984. PAUP phylogenetic analysis using parsimony. Version 2.3. Illinois Natural History Survey. Champaign. THEISSEN, F. AND H. SYDOW. 1917. Synoptische Tafeln. Annales Mycol. 15:389-491. TIFFNEY, B. H. AND E. S. BARGHOORN. 1974. The fossil record of the fungi. Occ. Papers Farlow Herb. 7:1-42. TULASNE, L. R. AND C. TULASNE. 1863. Selecta fungorum carpologia. 2:265-270. English tanslation. 1931, by W. B. Grove, edited by A. H. R. Butler and C. L. Shear. Oxford. VILGALYS, R. 1986. Phenetic and cladistic relationships in Collybia sect. Levipedes (Fungi: Basidiomycetes). Taxon 35:225-233. WAGNER, W. H. 1984. Origin and philosophy of the groundplan-divergence method of cladistics. Sys. Bot. 5:173-193. WHEELER, Q. and M. BLACKWELL. 1984. Fungus-insect relationships. Perspectives in ecology and evolution. Columbia University Press. New York. WILEY, E. O. 1981. Phylogenetics: the theory and practice of phylogenetic systematics. Wiley. New York. WORONOCHIN, N. N. 1915. Les fumagines du department de Sotshi. Trudy Prikl. Bot. Gen. Selek. 8:769-807. WORONOCHIN, N. N. 1925. Uber die Capnodiales. Ann. Mycol. 23:174-178.

Appreciation is expressed to mycologists T. Baroni, J. Boise, and R. Currah for manuscript reviews. I also thank Museum colleagues R. Brusca, S. George, and S. Keeley for thoughtful discussion and manuscript criticism.

MYCOTAXON

Vol. XXVII, p. 404 October-December 1986

NOTICE

Announcing a

GUIDE TO THE TREATMENT OF SANCTIONED FUNGAL NAMES

Subcommittee C of the IAPT Committee for Fungi and Lichens has elaborated a Report and a set of Proposals to alter the I.C.B.N., in order to clarify the situation of sanctioned fungal names (publication scheduled in Taxon, Nov. 1986).

A preliminary version of a Guide to the treatment of sanctioned names is ready, but still contains a few alternative solutions, on which decisions by the IAPT Committee for Fungi and Lichens and the next Botanical Congress are pending. After the Committee has given its vote, a modified, but still preliminary, version of this guide is to be published in Mycotaxon. Until then photocopies of the text are available upon request from Dr. W. Gams, Centraalbureau voor Schimmelcultures, P.O.Box 273, 3740 AG BAARN, Netherlands.

MYCOTAXON

Vol. XXVII, pp. 405-449 October-December 1986

THE USE OF ISOZYME ANALYSIS IN FUNGAL TAXONOMY AND GENETICS[1,2]

J. A. MICALES[3]

Department of Plant Pathology
Cornell University
Ithaca, NY 14853

M. R. BONDE and G. L. PETERSON

Foreign Disease-Weed Science Research Unit
Building 1301, Fort Detrick
Frederick, MD 21701

SUMMARY

Isozyme analysis, as performed with starch gel electrophoresis, is a valuable tool in the study of fungal taxonomy and genetics. Applications and procedures for this technique are presented and methods of data interpretation are discussed. It is recommended that in most studies a systematic approach be used whereby the presence of many specific enzymes is tested and the best buffer for their resolution is determined in an initial screen. This even-

---

[1] This study was carried out at Frederick, MD and partly funded by the United States-Israel Binational Agricultural Research and Development Fund Grant No. US-563-82.

[2] Mention of a trademark or propriety product does not constitute a guarantee or warranty of the product by USDA and does not imply its approval to the exclusion of other products that may also be suitable.

[3] Current address: USDA, U. S. Forest Service
Forest Products Laboratory
Box 3150
Madison, WI 53705

tually allows the greatest amount of useful information to be obtained with the least amount of effort when larger numbers of isolates are later examined.

INTRODUCTION

Isozyme analysis, as performed with starch gel electrophoresis, is a versatile and inexpensive technique which can be used to determine the amount of genetic variation among organisms. This procedure is commonly used in population genetic studies of fish (1, 19, 23), mammals (33, 42), insects (43), nematodes (16), and plants (9), but its application to fungal taxonomy and genetics is just being realized. The objective of this paper is to acquaint the reader with the theory of isozyme analysis and to provide detailed procedures so that the technique can be more widely applied. Reviews of this topic have been published (10, 41), but these have been written for plant and animal geneticists. This paper will stress the application of isozyme analysis for mycologists and plant pathologists and will address problems inherent to working with fungi.

Enzymes which are coded by different alleles or separate genetic loci frequently possess different electrophoretic mobilities. Such differences are due to variations in the amino acid content of the molecule, which in turn is dependent on the sequence of nucleotides in the DNA. Electrophoretic banding patterns are frequently predictable since they are dependent on the genetic and nuclear condition of the organism. Most mycologists and plant pathologists who use electrophoresis do not take advantage of this relationship and restrict their interpretation of electrophoretic data to simple "band-counting" techniques (34, 36); a genetic interpretation of the same data frequently provides more information about the genetics and taxonomy of a group of organisms. Genetic crosses may be necessary to confirm genetic interpretations, but certain banding patterns are readily recognizable from comparable studies in human and animal genetics (15). Much interest has been expressed in this technique, and it is currently being used in our laboratory to study the taxonomy and genetics of fungal taxa.

APPLICATIONS OF ISOZYME ANALYSIS

The ambiguous results of early studies of isozyme analysis with fungi (36) originally discouraged the application of this technique in mycology and plant pathology. More recently, isozyme analysis has been used to quantify genetic variation in *Agaricus* (21, 22, 31, 32), *Entomophthora* (20), *Neurospora* (38), *Peronosclerospora* (3), *Phytophthora* (40), and *Puccinia* (5, 6). The potential applications of isozyme analysis with fungi are limited only by the imagination of the researcher. There are at least three major areas in which isozyme analysis can be used. These include the clarification and delineation of fungal taxa, the identification of fungal cultures to the species or subspecies level, and the study of the genetics, including population genetics, of specific fungi. A list of representative fungi used for isozyme analysis, and enzymes found to give interpretable results, is presented in Appendix I.

Clarification and delineation of taxa - The interpretation of banding patterns in terms of specific alleles allows the determination of ratios of alleles expressed in common among fungal isolates; these ratios are an excellent means of determining phylogenetic relationships among organisms. In studies of closely related species, the assumption is made that the same loci are present and are being compared among isolates, even though the organisms may be from different species and the number of chromosomes may not be the same.

Isozyme analysis can be very helpful in solving taxonomic problems when there are few morphological parameters or when other characteristics are very plastic among isolates of the same species. It is relatively easy to detect 15 or more enzymes that can be used to differentiate and delineate closely related species. Examples of the use of isozyme analysis for taxonomic clarification have been presented by Royse and May (31, 32), Bonde et al. (3) and Micales et al. (24, 25).

Identification - Up to 90 different enzymes can be easily tested to determine whether a particular species can be distinguished from other species by means of the presently available techniques of isozyme analysis. Many of these enzymes will not be suited for a given fungal species. In examining the smut pathogen Tilletia indica Mit., Bonde et al. (2) readily found 29 enzymes of the 48 tested that were in high enough concentrations to warrant further studies.

With any species, some genetic loci tend to have little or no variation among individuals. These loci are termed "monomorphic" and are defined as loci in which 99% or more of the individuals have the most common allele. Although it is premature to estimate the average percentage of monomorphic loci for fungi in general, the work of Bonde et al. (2) suggests that about 50% of the genetic loci of T. indica are monomorphic. Tooley et al. (40) found that 11 of the 24 loci tested were monomorphic in Phytophthora infestans (Mont.) deBary. It is these monomorphic loci which perhaps should be stressed when comparing an "unknown" isolate to previously identified cultures in order to determine identity. Studies with other fungi in our laboratory suggest that some fungal species have considerably less allelic variation.

The importance of the correct identification of pathogens cannot be overstated. For example, regulatory agencies at the federal and state levels in the United States must correctly identify pathogens of regulatory significance. In some cases, all a regulatory official has to work with are a few spores in a shipment of produce; no symptoms are available. These spores may have been picked up from weeds during harvest; the identity of pathogens on weeds is often unknown. Isozyme analysis is a tool which can facilitate identification.

Fungal genetics - Isozyme analysis also is being used in fungal genetics. Genetic studies rely on loci which exhibit allelic variation. Tooley et al. (40) were able to demonstrate the probable random mating patterns of Phytophthora infestans in Mexico where the sexual stage of the pathogen exists; this was done by examining the genotypic distributions at two polymorphic loci. Almost every individual in the asexual population, representing the United States, Canada, and Europe, was heterozygous at these two loci, thus demonstrating the near absence of mating. Random mating also was demonstrated among sexual populations of Puccinia graminis f. sp. tritici by Burdon and Roelfs (5, 6).

Most studies have not been able to correlate specific isozyme patterns with differences in pathogenicity. One exception was reported by Burdon and Roelfs (5), who were able to find such a correlation in asexual populations of *Puccinia graminis* f. sp. *tritici*. This association was not true in sexual populations which had a much higher degree of genetic variability. Isozyme patterns of *Puccinia recondita* have been used to trace independent introductions of the pathogen to the United States (6). The potential for isozyme analysis in such studies of fungal genetics is great; the technique will be more widely used in the future as additional genetic markers are reported.

SELECTION OF FUNGAL TISSUES

Electrophoresis has been performed successfully with a wide variety of fungal tissues, including vegetative mycelia, conidia, basidiocarps, and sclerotia. Care must be taken in the selection of fungal tissues since inconsistent results may be obtained when a mixture of different tissues is used. Such variation may be due to the differential expression of alleles at different stages of development or from variations in the nuclear condition, as in the expression of the monokaryotic and dikaryotic stages of the organism. Variations in catalase banding patterns of conidia and vegetative mycelia have been reported for *Fusarium solani* (Mart.) Appel and Wr. (14). Similar differences have been observed among different portions of the basidiocarp in *Lentinus edodes* (Berk.) Sing. (27), *Coprinus cinerens* (Schaeff.) Cke. (26), and *Agaricus bisporus* (Lange) Imbach (28). The importance of using uniform tissue samples is demonstrated by such experiments.

SAMPLE PREPARATION

Proteins can be extracted from spores, mycelia, or fruiting bodies which have been grown in culture or collected in the field. Uniform conditions of light, temperature, and nutrition should be used when sample material is grown in culture in order to minimize the chance for the differential expression of induced enzymes. Ideally, samples should be collected at a specific stage of the growth curve; this is usually difficult to coordinate, and most researchers harvest their material after a specified period of growth. Initial studies should be conducted to determine the amount of electrophoretic variation detected at different stages of the growth cycle. The amount of protein in the mycelium may also vary with the stage of growth; protein assays (4, 17) should be conducted to determine the time of maximum protein production.

Proteins can be extracted from fungal tissues by a number of different procedures. Thin-walled structures, such as certain conidia and vegetative tissues, can be crushed with a glass rod after the sample has been frozen in liquid nitrogen. Lyophilization is frequently used with vegetative tissues and large fruiting bodies; this process removes the water from the sample and allows it to be readily crushed. The preparation of acetone powders can be used in lieu of lyophilization although we have obtained lesser quantities of enzymes with this technique. Large fungal structures, such as basidiocarps, ascocarps, or mycelial mats, can be disrupted with a variety of commercial homogenizers or simply crushed in a chilled mortar and pestle. Sample buffer is added to a freeze-dried sample before the sample begins to thaw or rehydrate. Non-frozen samples must be disrupted in a buffer solution. The amount of buffer to be added will vary with the nature and the size of the sample and is best determined empirically; there is a thin line between the addition of enough buffer for adequate sample size and diluting the sample below the level of detection. Proteins in the sample may precipitate if insufficient buffer is added or if the buffer is of the incorrect ionic strength.

The denaturation of enzymes must be prevented during and after homogenization; samples should be kept below 4° C during preparation and storage. Agents which inactivate proteases, such as polyvinylpyrrolidone (PVP), may be added to the sample buffer to prevent proteolysis.

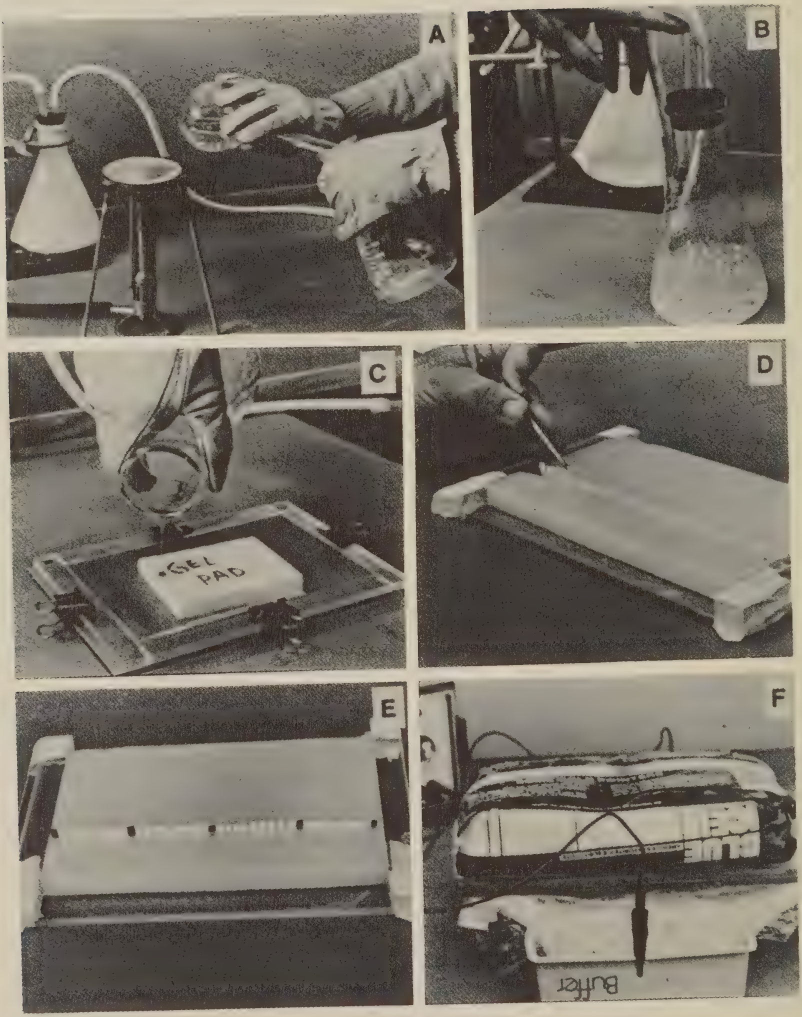
PREPARATION OF STARCH GELS

The preparation of starch gels is something of an art and requires some practice in order to obtain reproducible electrophoretic patterns. Many different electrophoretic systems are available commercially, but many researchers construct their own equipment with the inexpensive materials described below. Modifications of this system are possible if one needs to vary the size and depth of the desired gel. Diagrams of electrophoretic systems are presented by Conkle et al. (10), Werth (41), and May (19) and illustrated in photographs in Fig. 1.

Two types of electrophoretic experiments are usually distinguished. A "screening" run should be conducted early in a study with a few isolates (5-10) and a large number of stains and buffer systems. This experiment will determine which enzymes are active in the taxon and which buffers provide optimal resolution of each enzyme. The taxonomy and genetics of large numbers of isolates can then be studied in subsequent "analytical" runs, using the enzyme systems determined to be best in the screening run. The nature of the experiment (screen vs. analytical) will influence the preparation, sample application, and final handling of the gel; these differences will be detailed in the following sections.

Gel molds - Gel molds can be prepared by clamping plexiglass strips (163 x 20 x 6 mm and 215 x 20 x 6 mm) by means of binder clips around the four edges of a piece of plate glass (254 x 164 x 5 mm) as shown in Fig. 1. The thickness of the gel can be increased for comprehensive screening runs to test for large numbers of enzymes. This can be done by using thicker plexiglass strips or by securely taping two strips together. The mold should be placed on a level surface; uneven gel thickness will cause variations in enzyme migration rates in different regions of the gel.

Gel preparation - Gels can be prepared with 42 g of refined potato starch (Sigma Co., St. Louis, MO) per 300 ml gel buffer. Formulas for commonly used buffer systems are presented in Appendix II. Thicker gels for screening runs can be prepared with 70 g of starch in 500 ml of gel buffer. The starch is weighed and placed in a 1000 ml wide-mouthed flask (Fig. 1); approximately 1/3 of the gel buffer is added and the suspension vigorously swirled until the suspension is free of lumps. The flask can be placed on a stir plate at this time; the suspension should be continuously stirred to prevent settling of the starch. The remaining gel buffer is heated to boiling and rapidly poured into the flask which contains the starch. Care must be taken to prevent burns on the hands and face from the escaping steam; the boiling gel buffer should be initially swirled to allow the steam to escape. The hot suspension must be vigorously swirled


A
B
C
GEL
PAD
D
E
F
BLUE
Buffer

until it is uniformly mixed; the starch should be discarded if any lumps are visible since they will not be removed by continued mixing. The flask is then placed over a Bunsen burner and heated until boiling. The suspension must be swirled occasionally to prevent the starch from burning on the bottom of the flask. The suspension should be heated until it is boiling rapidly; it will also lose some of its viscosity and become somewhat transparent as the starch goes into solution. The flask then is removed from the flame, and the starch solution is degassed for approximately 20 sec to remove air bubbles. This usually is done with a vacuum formed by a water aspirator; a vacuum pump can also be used. A rubber stopper with two glass tubes is placed in the mouth of the flask. The hose attached to the vacuum source is placed over one glass tube; the other is covered with a finger tip so that the operator has direct control over the operation of the vacuum. A trap should also be inserted into the line to prevent the backflow of water from the aspirator into the gel. The length of time of degassing will vary with the volume of starch and the type of gel buffer; the vacuum should be applied until all small bubbles are removed from the solution and large bubbles are distributed uniformly throughout the mixture. The vacuum should be removed smoothly from the flask to prevent the formation of additional air bubbles. The solution is then poured carefully (Fig. 1) into the gel mold, and bubbles and small foreign particles can be removed before the starch cools and solidifies. The gels should be allowed to cool for at least one hour before electrophoresis. Gels should be covered with plastic wrap upon cooling to prevent loss of moisture. The plastic wrap should be spread as smoothly as possible, as wrinkles will cause depressions in the gel surface.

Fig. 1. Preparation of starch gels for electrophoresis. A) Starch is added to and dissolved in hot gel-buffer. B) Air is removed under vacuum and C) poured into a gel mold. D) Paper wicks with sample extracts are placed at the origin. E) Starch gel with 4 repeat series of sample extracts. After electrophoresis, gel will be cut vertically through lanes with marker dye and sliced horizontally to produce 8-10 thin layers. F) Starch-gel apparatus during electrophoresis run. Blue Ice® keeps gel cool.

APPLICATION OF SAMPLES TO THE GEL

The plastic wrap is removed from the gel surface after the samples have been prepared. A scalpel is used to cut around the periphery of the gel; the binder clips and long plexiglass strips can be removed at this time. Excess starch is trimmed from the surface of the shorter plexiglass strips. The origin of the gel is formed by making a cut across the length of the gel approximately 2.5-3.0 cm from the cathodal edge (Fig. 1). The cut must be perpendicular to the gel surface and reach the bottom of the gel. The cathodal strip is pulled away from the cut surface; this facilitates the application of samples to the anodal edge of the origin.

Small filter paper wicks are used to apply the protein to the gel (Fig. 1). Wicks can be cut from large filter paper sheets or strips; a variety of filter paper grades can be used, but thick grades will waste precious sample material. Whatman No. 3 filter paper is used in our laboratory. The size of the rectangular wicks varies with the number of samples that are to be placed on the gel. We usually use wicks that are 2-3 x 12-15 mm; longer wicks are required for thicker screening gels.

Wicks are dipped into the crude homogenate and removed after the sample has risen by capillary action to within 1/3 of the top. Do not allow the wick to touch solid fungal material since this will cause streaking in the gel. The wick is then placed vertically on the anodal surface of the origin; the bottom of the wick should be flush with the bottom of the gel. Samples should be spaced with approximately 1 mm between each wick (Fig. 1); up to forty wicks can be applied to a gel in this manner. Larger spaces can be used at certain intervals to facilitate the determination of the location of each sample on the gel after staining. Food coloring is diluted with sample buffer (1:1) and applied to two wicks; these dye markers are placed at each end of the gel so the extent of migration during and after electrophoresis can be monitored.

The arrangement of samples on the gel depends on the type of experiment. In a screening run, we generally use a sequence of 8-10 samples repeated four times (Fig. 1). Dye markers are placed between each group at the origin to facilitate determination of where to cut the gel following electrophoresis. A larger number of samples is used for analytical experiments. The sequence of samples should be repeated at least once in an analytical run if sufficient space is available; variations in migration in different portions of the gel can then be detected and this greatly facilitates interpretation of results. It is advisable to repeat one or two samples at intervals on the gel; this provides a standard to which each sample can be compared. If particular comparisons are desired among isolates, these samples should be placed in close proximity to insure accurate analysis.

ELECTROPHORESIS

The cathodal strip is moved back into place after the wicks have been applied (Fig. 1). The two pieces of gel must make firm contact in order to allow the electrode buffer to move freely between them. The surface of the gel is then covered with plastic wrap which is folded back 1.5 cm from the anodal and cathodal edges of the gel. Buffer trays (we styled them from the tops of plastic butter dishes) are filled with the appropriate electrode buffer; absorbant, disposible cloths (e.g. Handiwipes®) are placed in these trays. These cloths should be folded into three layers and thoroughly washed of all detergent before use. The leading edge of the cloth is placed on the surface of the gel making certain that there is good contact between the cloth and the gel. The remaining plastic wrap is folded back over the surface of the absorbant cloth. Platinum electrode wires, which are soldered onto the end of alligator clips attached to a DC power supply, are inserted into each electrode buffer tray, with the cathode (negatively charged, black lead) closest to the gel origin (Fig. 1). Power is supplied to the gel and adjustments are made so that the levels of voltage and current are appropriate. Proteins are allowed to migrate out of the wicks; this process takes about 15 min and can be estimated by the rate of migration of the tracker dye. After this time interval, the power is turned off, the absorbant cloth on the cathodal end is lifted, and the wicks are removed. The two slices of gel are firmly pushed together, and the absorbant cloth and plastic wrap reapplied. The gels must be kept cool during the electrophoretic run. We use Blue Ice® packs on top of two layers of 5 mm-thick plate glass placed directly on the surface of the gel to insure uniform cooling (Fig. 1); commercial cooling devices also are available. Power is resupplied; the levels of current and voltage are readjusted and monitored throughout the electrophoretic run. A typical experiment requires approximately 2.5-3.0 hr of migration for adequate resolution of protein bands, although some researchers use lower voltage and current settings and allow the gel to run for longer periods of time.

A list of gel buffer systems commonly used in our laboratory is presented in Appendix II.

SLICING THE GELS

After electrophoresis is completed, the power supply is turned off, and the plastic wrap, absorbant cloths, buffer trays, and plexiglass strips are removed from the gel. The anodal strip above the dye markers is cut away, and an identifying mark is cut into the anodal and cathodal gels in a standardized position for proper orientation of the gel after staining. One advantage of starch gel electrophoresis is that several thin, horizontal slices can be made from each gel; these can be stained individually for the detection of different enzymes. Commercial gel slicers are available, but many researchers use plexiglass guides (300 x 25 x 1 mm) and nylon sewing thread ("invisible thread") or low test fishing line. Slices are cut by sequentially stacking the plexiglass guides along the long edges of the gel and by drawing the thread through the gel over the surface of the guides (Fig. 2). The uppermost slice is usually discarded due to the thick "skin" which is formed during cooling; electrophoretic migration is frequently inconsistent in this uppermost region of the gel. The remaining slices are gently removed from the gel and placed in styrofoam staining trays; the side of the slice which was closest to the center of the gel should be placed upright since enzyme concentration is highest in this region.

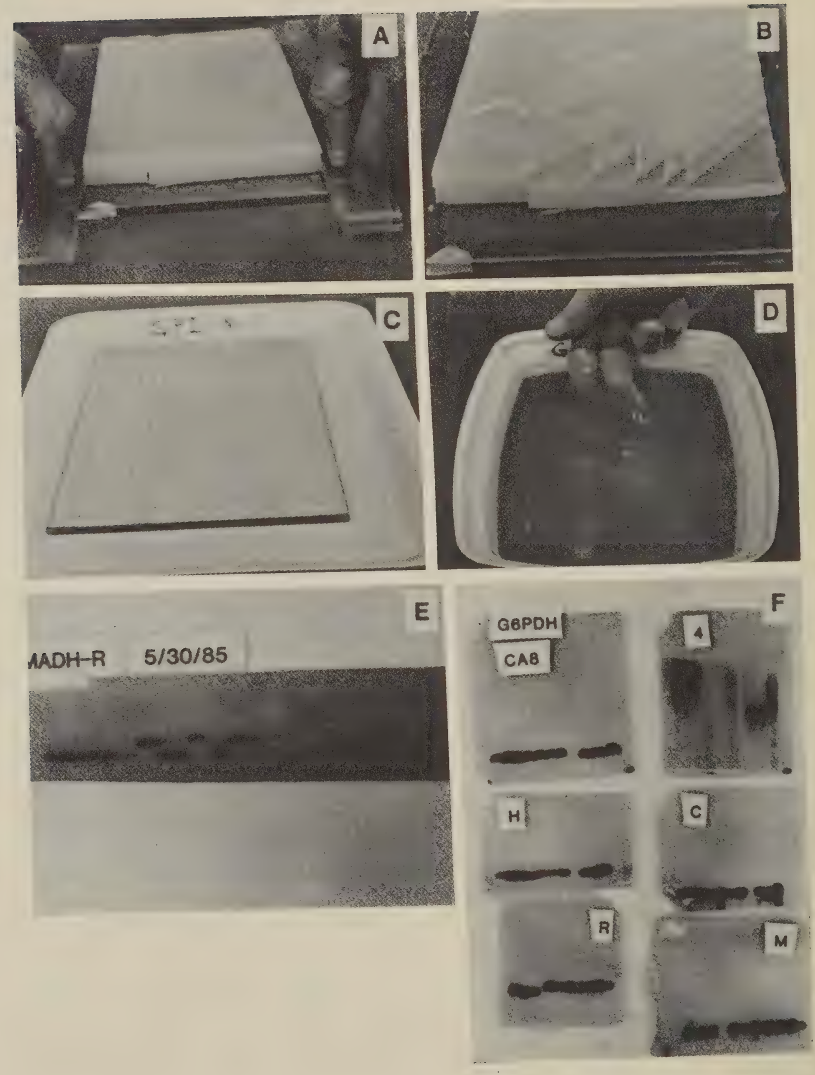
Enzyme screens require many more duplicate gel pieces than do analytical runs, thus allowing the testing for the presence and resolution of a large number of enzymes from a single gel. The procedure used for cutting gels for enzyme screens is similar to that described above, except that vertical cuts must also be made through dye markers to separate the individual groups of samples. This is usually done after the horizontal slicing has been accomplished. A distinguishing cut or notch must be placed in each section of the gel so that the orientation of samples and identification of the gel buffer system can be maintained during later staining and manipulation of the many gel pieces. One section of each gel is then placed in each staining tray or on individual glass plates, the latter for agar overlays, fluorochromes, and certain azo dyes (see Appendix III), so that the different gel buffers can be tested in each staining solution.

STAINING

Specific activity stains are used to detect the location of specific enzymes after completion of electrophoresis. The detection of the activity of individual enzymes is possible because the appropriate substrates and cofactors required for activity are provided in the staining solution; the enzymatic reaction then forms a colored product, either through direct activity on a dye or by involving other enzymes in a series of reactions with the generation of a colored product as the final result. Fluorescent products can be detected with ultraviolet light; alternatively, non-fluorescent products can be visualized as a negative stain by reacting the starch with a fluorescent compound. The biochemistry of such staining reactions is discussed in Gabriel (13).

Staining recipes for 43 commonly studied enzymes are presented in Appendix III; additional staining recipes can be found in Harris and Hopkinson (15), Cheliak and Pitel (7), Conkle et al. (10), Gabriel (13), and Shaw and Prasad (35). We weigh stain components into pre-labelled styrofoam cups during the electrophoretic run. This process can be done quite rapidly if stains with similar reagents are grouped together. The amounts of certain inexpensive reagents can be estimated; precise measurements are usually not necessary since excess reagent will not affect the reaction. One or two key enzymes or cofactors should be left out initially to prevent premature reactions; these then can be added just before the staining solution is poured into the staining tray.

Once the stain has been poured into the staining tray, the tray should be lightly shaken so that the gel


A
B
C
D
E
MADH-R
5/30/85
F
G6PDH
CA8
4
H
C
R
M

slice can move freely in the staining solution, thus allowing maximum contact of the staining solution with both surfaces of the gel. The trays then are placed in a 37° C oven to speed development of the enzyme bands. Since many stains are sensitive to light, the oven door should be kept closed as much as possible. Agar overlays are frequently used for enzymes of low activity or low concentration; this procedure is described in Appendix III.

GENETIC INTERPRETATION

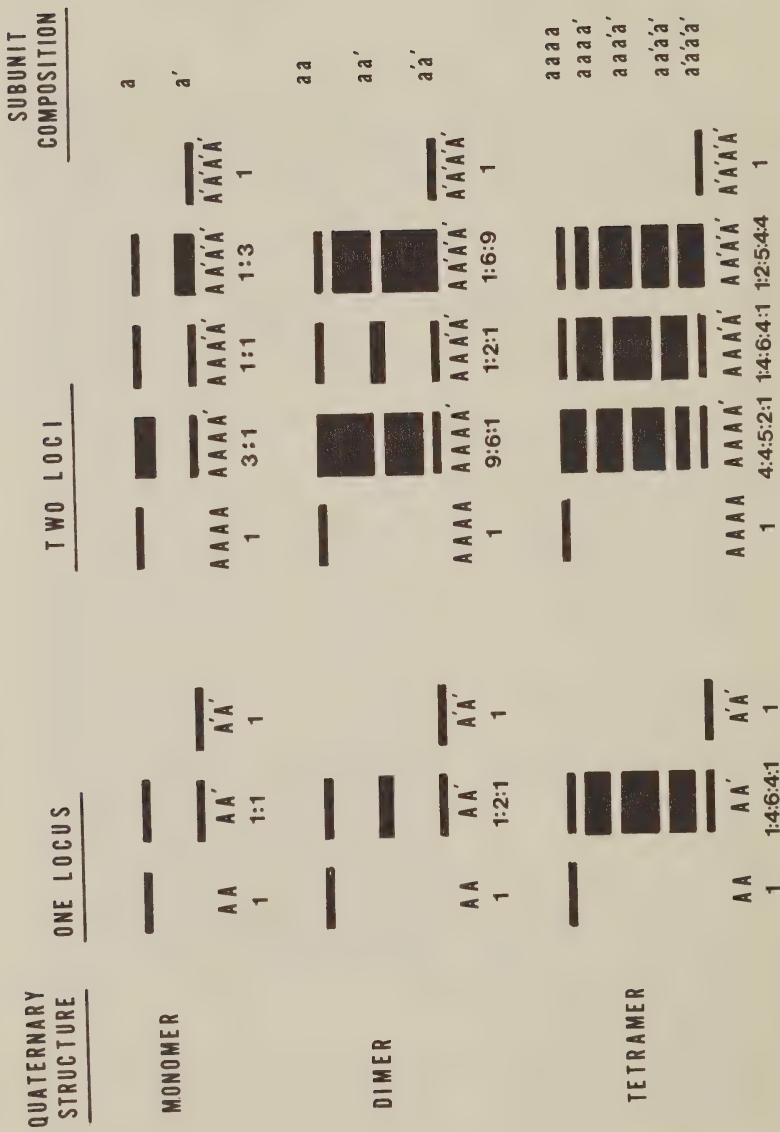
Genetic interpretations of electrophoretic banding patterns can produce large amounts of information about the nuclear condition and genetic make-up of the organism. A brief summary of the principles of genetic interpretation is provided (Figs. 3-5); the reader also is referred to more detailed accounts (12, 15).

Isozymes can be defined as multiple molecular forms of a given enzyme; these forms usually have similar, if not identical, enzymatic properties. Isozymes can occur within a single individual or among different individuals of the same species. Isozymes also can be localized in specific tissues of an organism or be compartmentalized within different areas of the cell. Only those isozymes with amino acid compositions of different net charge, or those which result in large differences in the shape of the enzyme, will be differentiated by electrophoresis. This represents only one third of all possible isozymes which may be present within a genetic system.

Detectable isozymes can arise from three different genetic and biochemical phenomena: 1) multiple allelism at a single locus; 2) multiple loci coding for a single enzyme; and, 3) post-translational processing and the formation of secondary isozymes (15). All of these situations must be considered when trying to interpret

---

Fig. 2. A) Analytical gel following removal from mold. B) Gel sliced to make 8-10 thin layers, each to be stained for a separate enzyme. C) Gel layer to be stained on a glass plate using an agar overlay. D) Gel layer during staining in staining tray. E) Gel layer following staining for mannitol dehydrogenase to detect 2 alleles and E) Six gel pieces stained for glucose-6-phosphate dehydrogenase in a gel-buffer screen.


QUATERNARY STRUCTURE
ONE LOCUS
TWO LOCI
SUBUNIT COMPOSITION
MONOMER
AA
1
AA'
1:1
A'A'
1
AAAA
1
AAAA'
3:1
AAA'A'
1:1
AA'A'A'
1:3
A'A'A'A'
1
a
a'
DIMER
AA
1
AA'
1:2:1
A'A'
1
AAAA
1
AAAA'
9:6:1
AAA'A'
1:2:1
AA'A'A'
1:6:9
A'A'A'A'
1
aa
aa'
a'a'
TETRAMER
AA
1
AA'
1:4:6:4:1
A'A'
1
AAAA
1
AAAA'
4:4:5:2:1
AAA'A'
1:4:6:4:1
AA'A'A'
1:2:5:4:4
A'A'A'A'
1
aaaa
aaaa'
aaa'a'
aa'a'a'
a'a'a'a'

electrophoretic data.

1. Multiple allelism at a single locus: Variations in banding patterns frequently are caused by the expression of multiple alleles at a single locus, each allele coding for a structurally distinct polypeptide chain. The actual banding pattern is dependent on the number of alleles present at the locus, which in turn is dependent on the nuclear condition (monokaryotic, dikaryotic), ploidy number (haploid, diploid, polyploid), and genetic make-up (homozygous, heterozygous) of the organism. Individuals which are haploid or homozygous will produce simple banding patterns due to the expression of a single allele. Organisms which are diploid and heterozygous will produce more complex banding patterns due to the expression of two separate alleles.

The banding pattern is also dependent on the quaternary structure of the enzyme. Enzymes which are monomeric are composed of a single polypetide chain; monomeric isozymes of a heterozygote will appear as a mixture of the isozymes produced by the two corresponding homozygotes. Multimeric enzymes consist of two or more polypeptide chains; heteromeric (hybrid) bands will be produced by heterozygous individuals as the result of random combination of polypeptide chains to produce hybrid enzyme molecules. Heteromeric bands cannot occur unless different alleles (coding for different polypeptide chains) are present in the same individual. The expected banding patterns for monomeric, dimeric, and tetrameric enzymes coded by two alleles at a single locus are presented in Fig. 3. The frequency of occurrence of the different isozyme molecules, assuming random combinations of polypeptide chains, should follow Mendelian ratios; the ratio of isomers formed in heterozygotes will

---

Figure 3: Predicted banding patterns for one locus with two alleles (A and A') and two segregating loci which share the same two alleles for monomeric, dimeric and tetrameric enzymes of a diploid organism. Genotypes are listed beneath each banding pattern (phenotype); alleles are designated by capital letters. The subunit composition of each protein band is shown on the right; lower case letters refer to subunit designations. The expected ratios of banding intensity for each phenotype is presented beneath the genotype. Adapted from May (19).

be 1:1 for monomers, 1:2:1 for dimers, 1:3:3:1 for trimers and 1:4:6:4:1 for tetramers. In some cases, a particular polypeptide will not contribute equally to the activity of the enzyme due to a slow rate of synthesis, low stability, or a tendency to break down before it can assemble into the final enzyme. A polypeptide can also reduce the effectiveness of the enzyme by decreasing its stability or reducing its catalytic ability; such enzymes would not be detected in the expected ratios of intensity on the electrophoretic gel. A complex series of banding patterns is produced when three or more alleles are present in a population of organisms (15). Further examples are demonstrated in Fig. 4.

2. Multiple loci: Multiple loci can also code for a structurally distinct series of isozymes; up to four different loci have been reported for some enzymes. Multiple loci are thought to originate from gene duplications and subsequent divergence by point mutations; they are frequently expressed in different tissues of an organism or compartmentalized indifferent areas of the cell. Isozymes coded by different loci are frequently detected in separate regions of the gel due to their greater differences in charge and conformation than usually associated with multiple alleles at a single locus. Heteromeric bands can be formed by polypeptides coded by different loci; banding patterns thus can become quite complex when a number of different loci and alleles are involved (Fig. 5). The distribution of loci is usually constant within a given species (15).

3. Secondary isozymes: Banding sequences may not appear to follow expected genetic patterns due to post-translational processing and other events which form secondary isozymes. Common modifications include the deamidation of glutamine and asparagine residues, acetylations, oxidation of sulfhydryl groups, additions and removals of carbohydrate and phosphate moieties, cleavage of the enzyme by proteases, and the aggregation or polymerization of the molecule. The formation of such secondary isozymes is usually quite uniform and can be recognized by the production of a series of bands for each allele (15).

Another process responsible for the generation of secondary isozymes is conformational isomerism. Some enzymes may have several stable configurations which vary

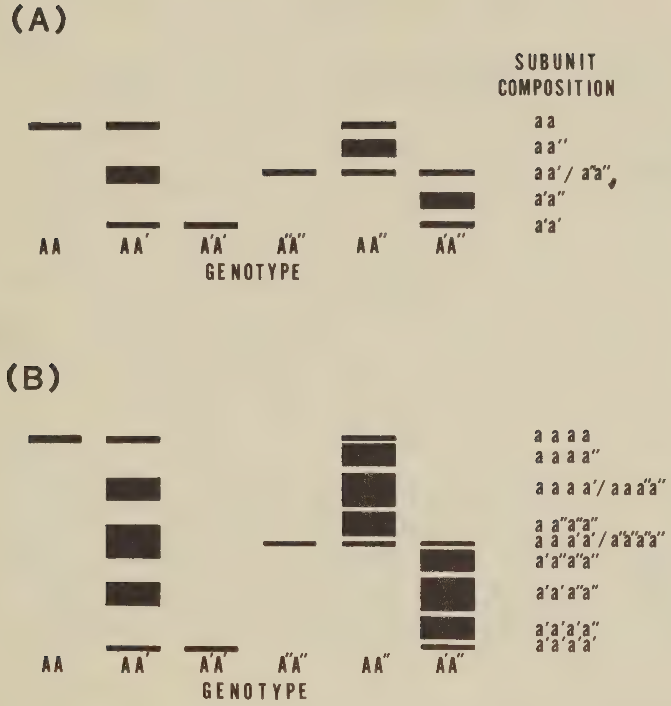

(A)
SUBUNIT
COMPOSITION
a a
a a''
a a'/ a''a''
a'a''
a'a'
A A
A A'
A'A'
A''A''
A A''
A'A''
GENOTYPE
(B)
a a a a
a a a a''
a a a a'/ a a a''a''
a a''a''a''
a a a'a'/ a''a''a''a''
a'a''a''a''
a'a'a''a''
a'a'a'a''
a'a'a'a'
A A
A A'
A'A'
A''A''
A A''
A'A''
GENOTYPE

Fig. 4: Predicted banding patterns of dimeric (A) and tetrameric (B) enzymes coded by a single locus and three electrophoretically distinct alleles (A, A' and A'') of a diploid organism. Genotypes are listed below each banding pattern (phenotype). The subunit composition of each protein band is shown on the right; lower case letters refer to subunit designations. Adapted from May (19).

in tertiary or quaternary structure; these will frequently have different electrophoretic mobilities. All configurations should be isolated from a single preparation, and a series of electrophoretic bands should be observed for a single allele (15).

Enzymes which require cofactors, such as NAD and NADP, may vary in their electrophoretic mobility depending on the degree of saturation of the enzyme with

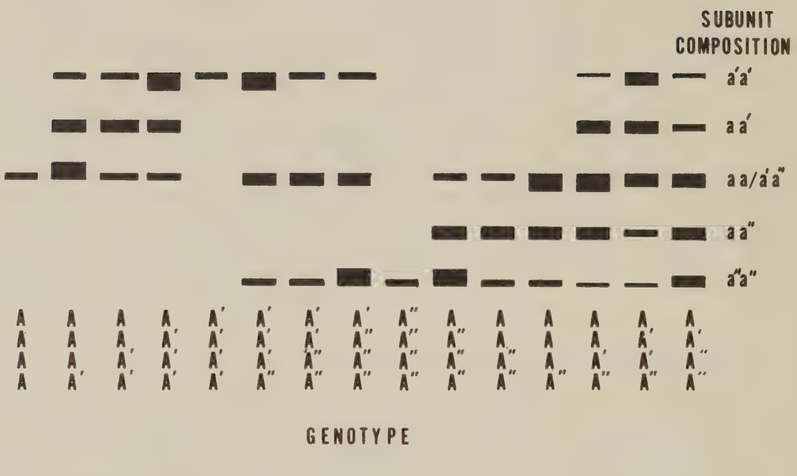


Fig. 5: Predicted banding patterns of a dimeric enzyme coded by two loci which share the same three electrophoretically distinct alleles (A, A' and A''). Genotypes are listed below each banding pattern (phenotype). The subunit composition of each protein band is shown on the right; lower case letters refer to subunit designations. Adapted from May (19).

the cofactor. The amount of cofactor in the staining solution must not be limiting or inconsistent results are likely to occur. It may be necessary to add the cofactor to the sample buffer and/or the gel buffer in order to maintain the stability of the enzyme during electrophoresis (15).

Artifact bands can also arise from the proteolysis of the sample during extraction and storage; sample material can be preserved at -80° C or below, however samples should not be kept for more than one year as activity will generally decrease. Enzymes can also be bound to other cell constituents and will not migrate freely in the electrophoretic field. Alternate methods of sample extraction and storage may be necessary; stabilizing agents may be added to the sample to protect the enzymes from other cell constituents (15).

GENIC NOMENCLATURE AND PRESENTATION OF RESULTS

Taxonomic and genetic information can be summarized by several different methods; the technique of May et al. (23), as further described by Bonde et al. (3) allows direct comparisons from one experiment to another regardless of absolute migration distances if standard alleles are included in each test. Alleles at a single locus are described by their relative anodal or cathodal movement from the origin as compared to the movement of the homomeric protein coded by the most frequently observed allele (which is designated 100). A dimeric heterozygote (or heterokaryon), which produces three bands on the electrophoretic gel, would be designated by two different alleles (e.g. 100/130); a diploid homozygous individual would be described by two identical alleles (100/100 or 130/130). The frequency of shared alleles can be used to calculate the coefficient of similarity among organisms. Several different formulas can be used to determine this quantity (12, 30); commercial computer programs are also available to do these calculations. The final information can be summarized in the form of a dendrogram; this type of diagram can be constructed with a variety of clustering procedures (11, 12) using commercial computer programs.

TROUBLESHOOTING

Problems sometimes develop during electrophoresis that threaten the success of the run or result in inconsistencies among runs performed at different times. These problems frequently can be corrected or avoided if proper steps are taken. A list of common problems, along with their probable causes and possible corrections, is presented below.

I. Problems with preparation of starch solution.

    A. Flecks or lumps appear in hot solution.
        1. Cause:
            a. Starch was not mixed well with cold buffer.
            b. Starch was allowed to settle in the cold buffer after it was mixed.
            c. Heated buffer was not hot enough when poured into cold starch suspension.

   - d. Flask was not thoroughly cleaned from previous experiment and flecks of dried starch have come off the glass.

2. Correction: Discard solution and begin again, making certain that the starch is mixed well in the cold buffer, that the remaining buffer is brought to a rolling boil, and that all glassware is thoroughly clean.

B. Starch is thick and lumpy when poured into gel mold.

1. Cause: Starch has cooled during the degassing process.

2. Correction: Discard the solution and repeat gel preparation. Degas solution for shorter period of time.

II. Problems with gel consistencies or dimensions.

A. Gels soft and watery.

1. Causes:
   - a. Starch not cooked long enough.
   - b. Improper amount of gel buffer added to starch.
   - c. Starch not degassed long enough.
   - d. Gels are still too warm and need additional time to cool.
   - e. Gels allowed to warm up during electrophoresis process.

2. Corrections: Repeat gel preparation, making certain that the solution is mixed properly. Increase periods of heating and degassing; be certain that the gels are cooled sufficiently before they are trimmed. Make certain that cooling apparatus is adequate for electrophoretic conditions. It may be necessary to decrease current and voltage and allow the gel to run for a longer period of time.

B. Gels hard and difficult to slice.

1. Causes:
   - a. Starch cooked or degassed too long.
   - b. Gel frozen in center from ice packs.

2. Corrections: Determine whether center of gel is frozen; uneven electrophoretic mobilities can be expected and comparisons will be difficult to make in this event. Avoid this in future runs by placing glass plates beneath ice pack or otherwise altering cooling apparatus. If gel is not frozen, repeat gel preparation

while decreasing amount of heating and degassing.

C. Gel uneven in thickness.
  1. Causes:
    a. Gel mold is not level.
    b. Plexiglass strips are not firmly clamped forming a slow leak on one side of the gel.
  2. Correction: Repeat gel preparation making certain that gel mold is level and that clamps are firmly in place.

III. Problems with establishing proper voltage and current.

A. No current or voltage registered on power supply.
  1. Causes:
    a. Power supply not plugged in, with blown fuse, or malfunctioning.
    b. Broken wire in anode or cathode lead.
  2. Corrections: Attach gel to second power supply with the same leads; if voltage and current still do not register, repeat process with another set of leads.

B. Current reading is zero at proper voltage.
  1. Cause: Corrosion on electrode prevents contact with buffer.
  2. Correction: Remove corrosion with file; resolder platinum wire if necessary.

C. Current reading is infinite, voltage reading is correct.
  1. Causes:
    a. Short circuit in power supply, electrode leads, buffer systems or gel.
    b. Incorrect settings on power supply.
  2. Corrections: Substitute a second power supply to determine whether short circuit is in gel or power supply. With power turned off, look for possible short circuit in electrode leads, buffer or gel systems. Check settings on power supply to see if they fall within the proper range (i.e. set at 0-200 mA instead of 0-20 mA).

D. Voltage is too high (or current is too low).
  1. Causes:
    a. Separation of gel at origin.
    b. Poor contact of absorbant cloths with gel surface.

      c. Obstruction in flow of electrode buffer through absorbant cloths.
      d. Electrode buffer at improper ionic strength - too low.
      e. Not enough electrode buffer in tray.

2. Corrections: After turning power off, remove plastic wrap and realign absorbant cloths on gel surface making certain that there are no wrinkles and folds which would restrict flow of electrode buffer. Recover with plastic and turn power on. If voltage is still too high, add more electrode buffer to tray. If this also does not correct the problem, run the gel as it is but allow it to go for a longer period of time.

E. Voltage is too low (or current is too high).
   1. Causes:
      a. Electrode buffer at improper ionic strength - too high.
      b. Too much electrode buffer in tray.

2. Corrections: Remove some of electrode buffer from tray. If this does not affect voltage, run gel for shorter period of time. Be certain that gel does not overheat; do not allow current to go higher than that described for the particular buffer.

IV. Problems with uneven migration of dye front.

A. Dye front is concave when viewed from origin.

1. Cause: Uneven cooling of gel; center of gel is cooler than edges.

2. Correction: Modify cooling system so that gel temperature does not exceed 4° C and gel is cooled uniformly.

B. Dye front is convex when viewed from origin.

1. Cause: Uneven cooling of gel; center of gel is warmer than edges.

2. Correction: Modify cooling system so that gel temperature does not exceed 4° C and gel is cooled uniformly.

C. Dye front is straight but higher on one side than the other.
   1. Cause:
      a. Gel of unequal thickness.
      b. Anodal electrode is worn or corroded.
      c. Gel has separated at origin.

d. Plastic wrap is not positioned in straight line along the edge of the gel.

2. Correction: After power is turned off, remove plastic wrap and check whether the gel has separated at the origin. Realign plastic wrap and continue run. Replace worn and corroded electrodes.

D. Dye front is wavy and uneven.

1. Cause:
   - a. Uneven cooling of gel.
   - b. Gel has separated at origin.
   - c. Absorbant cloths not making proper contact with gel.

2. Correction: After power is turned off, remove plastic wrap and check whether gel has separated at origin. Reposition absorbant cloths, making certain that they are in proper contact with the gel. Modify cooling system so that gel temperature does not exceed 4° C and gel is cooled uniformly.

E. Dye front migrates slower in one gel than another gel of the same system.

1. Cause:
   - a. Gels are of different thicknesses.
   - b. Electrodes are corroded.
   - c. Unequal levels of electrode buffers are present in the trays.
   - d. New absorbant cloths are being used.

2. Correction: Decrease voltage of faster running gel or allow the slower gel to run for a longer period of time.

F. Dye front migrates into narrow, "cathodal" section of the gel.

1. Cause: Electrode leads have been reversed in buffer wells.

2. Correction: Reverse leads and allow gel to run for an additional period of time if this is discovered early in the electrophoretic process. Not much can be done if this reverse is discovered towards the end of the procedure; the "cathodal" strip can be stained but enzyme separation is usually not reliable.

V. Problems with resolution of protein bands.

A. Bands smeared or streaked from origin.

1. Cause:

a. Insoluble fungal material on wick or cut surface of origin continuously supplies protein to gel.
b. Low ionic strength of sample buffer allows precipitation of proteins in sample. Precipitation will also occur if not enough sample buffer is added to the crude homogenate.
c. Air bubble in gel, or gels have separated at origin.
d. Amylase may be present in crude homogenate.

2. Correction: Since streaking is not detected until after the gels have been stained, there is nothing that can be done to save the preparation. In future electrophoretic runs, be certain that wicks do not contain insoluble material and the proper amount of sample buffer is added. Examine gels for air bubbles while starch is still molten and make certain that the gels meet firmly at the origin.

B. Bands with poor resolution and poor separation.

1. Cause:
   a. Gel and electrode buffers at improper pH or ionic strength.
   b. Wicks are too large so that too much sample is applied to the gel.
   c. Samples permitted to diffuse before or after electrophoresis.
   d. Gel developed too long in staining solution.

2. Correction: Conduct a screening run to determine which buffer systems should be used with a particular enzyme. Do not use oversized wicks. Do not allow gels to sit for long periods of time before or after electrophoresis. Analyze gels rapidly; photograph each gel as soon as it is developed.

C. Protein bands very light and difficult to see.

1. Cause:
   a. Sample too dilute either through the addition of too much sample buffer or improper sample preparation and extraction procedures.
   b. Gel not completely developed in staining solution.

2. Correction: Allow gels to develop for longer period of time in the staining solution. If this does not help, reevaluate procedures of sample preparation.

Weak reactions can sometimes be stabilized if the enzyme substrate, or protease inhibitors, are added to the sample buffer. The use of agar overlays may also sharpen staining reactions.

D. Protein bands do not move away from origin.

1. Cause: Improper pH or ionic strength of electrode or gel buffer.

2. Correction: Conduct a screening run to determine which buffer systems should be used for a particular enzyme. Make certain that buffers have been made properly.

E. No bands are detected.

1. Cause:
    a. Staining solutions have been mixed improperly.
    b. Chemicals or stain buffers have deteriorated.

2. Correction: Check stain recipes to determine whether all components have been added; chemicals which have been left out can often be added later with no detrimental effects. If this does not work, remix stain buffers or order new chemicals. Be certain that chemicals are stored under proper conditions.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to photographer Austin D. Twigg, TASC, Fort Detrick and secretary Gwen Bowlus, USDA, FD-WSRU, for their excellent contributions toward the preparation of this manuscript.

LITERATURE CITED

1. Allendorf, F. W., Mitchell, N., Ryman, N., and Stahl, G. 1977. Isozyme loci in brown trout (*Salmo trutta* L.): detection and interpretation from population data. Hereditas 86:179-190.
2. Bonde, M. R., Peterson, G. L., Dowler, W. M., and May, B. 1985. Comparison of *Tilletia indica* isolates from India and Mexico by isozyme analysis. (Abstr.) Phytopathology 75:1309.
3. Bonde, M. R., Peterson, G. L., Dowler, W. M., and May, B. 1984. Isozyme analysis to differentiate species of *Peronosclerospora* causing downy mildews of maize. Phytopathology 74:1278-1283.

4. Bradford, M. M. 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein using the principle of protein-dye binding. Anal. Biochem. 72:248-254.
5. Burdon, J. J., and Roelfs, A. P. 1985. The effect of sexual and asexual reproduction on the isozyme structure of populations of Puccinia graminis. Phytopathology 75:1068-1073.
6. Burdon, J. J., and Roelfs, A. P. 1985. Isozyme and virulence variation in asexually reproducing populations of Puccinia graminis and P. recondita on wheat. Phytopathology 75:907-913.
7. Cheliak, W. M., and Pitel, J. A. 1984. Techniques for starch gel electrophoresis of enzymes from forest trees. Information Report PI-X-42. Petawawa National Forestry Institute, Canadian Forest Service. 49 pp.
8. Clayton, J. W., and Tretiak, D. N. 1972. Amine-citrate buffers for pH control in starch gel electrophoresis. J. Fish. Res. Board Can. 29:1169-1172.
9. Conkle, M. T. (technical coordinator). 1981. Proceedings of the symposium on isozymes of North American forest trees and forest insects. Gen. Tech. Rep. PSW-48, Pacific Southwest Forest and Range Exp. Stn., Forest Serv., U. S. Dep. Agric., Berkeley, CA. 64 pp.
10. Conkle, M. T., Hodgskiss, P. D., Nunnally, L. B., and Hunter, S. C. 1982. Starch gel electrophoresis of conifer seeds: a laboratory manual. Gen. Tech. Rep. PSW-64. Pacific Southwest Forest and Range Exp. Stn., Forest Serv., U. S. Dep. Agric., Berkeley, CA. 18 pp.
11. Dunn, G., and Everitt, B. S. 1982. An Introduction to Mathematical Taxonomy. Cambridge University Press, New York. 152 pp.
12. Ferguson, A. 1980. Biochemical Systematics and Evolution. Wiley and Sons, New York. 194 pp.
13. Gabriel, O. 1971. Locating enzymes on gels. In: Methods of Enzymology - Vol. 2. p. 578-604. S. P. Colowick and N. O. Kaplan (eds.). Academic Press, New York.
14. Hall, R. 1967. Proteins and catalase isoenzymes from Fusarium solani and their taxonomic significance. Austral. J. Biol. 20:419-428.
15. Harris, H., and Hopkinson, D. A. 1976. Handbook of Enzyme Electrophoresis in Human Genetics [with

supplements]. Oxford American Elsevier Publishing Co., New York.

16. Huettel, R. N., Dickson, D. W., and Kaplan, D. T. 1983. Biochemical identification of the two races of Radopholus similis by starch gel electrophoresis. J. Nematol. 15:338-344.
17. Lowry, O. H., Rosebrough, N. J., Farr, A. L., and Randall, R. J. 1951. Protein measurement with the Folin phenol reagent. J. Biol. Chem. 193:265-275.
18. Markert, C. L., and Faulhaber, I. 1965. Lactate dehydrogenase isozyme patterns of fish. J. Exp. Zool. 159:319-332.
19. May, B. 1980. Salmonid genome: evolutionary restructuring following a tetraploid event. Ph.D. Thesis, The Pennsylvania State University. 199 pp.
20. May, B., Roberts, D. W., and Soper, R. S. 1979. Intraspecific genetic variability in laboratory strains of Entomophthora as determined by enzyme electrophoresis. Exp. Mycol. 3:289-297.
21. May, B., and Royse, D. J. 1982a. Confirmation of crosses between lines of Agaricus brunnescens by isozyme analysis. Exp. Mycol. 6:283-292.
22. May, B., and Royse, D. J. 1982b. Genetic variation and joint segregation of biochemical loci in the common meadow mushroom, Agaricus campestris. Biochem. Genet. 20:1165-1173.
23. May, B., Wright, J. E., and Stoneking, M. 1979. Joint segregation of biochemical loci in Salmonidae: Results from experiments with Salvelinus and review of the literature on other species. J. Fish. Res. Board Can. 36:1114-1128.
24. Micales, J. A., Bonde, M. R., Peterson, G. L., and Fry, W. E. 1985. Differentiation of Peronosclerospora species by isozyme analysis. (Abstr.) Phytopathology 75:1339.
25. Micales, J. A., Stipes, R. J., and Bonde, M. R. 1985. On the conspecificity of Endothia eugeniae and Cryphonectria cubensis. (Abstr.) Va. J. Sci. 36:123.
26. Moore, D., and Jirjis, R. 1981. Electrophoretic studies of carpophore development in the basidiomycete Coprinus cinereus. New Phytol. 87:101-113.
27. Okunishi, M., Yamada. K., and Komagata, K. 1979. Electrophoretic comparison of enzymes from basidiomycetes in different stages of development. J. Gen. Appl. Microbiol. 25:329-334.

28. Paranjpe, M. S., Chen, P. K., and Jong, S. C. 1979. Morphogenesis of Agaricus bisporus: Changes in protein and enzyme activity. Mycologia 71:469-478.
29. Ridgway, G. J., Sherburne, S. W., and Lewis, R. D. 1970. Polymorphisms in the esterases of Atlantic herring. Trans. Am. Fisheries Soc. 99:147-151.
30. Rogers, J. S. 1972. IV. Measures of genetic similarity and genetic distance. Stud. Genet. 7:145-153.
31. Royse, D. J., and May, B. 1982a. Use of isozyme variation to identify genotypic classes of Agaricus brunnescens. Mycologia 74:93-102.
32. Royse, D. J., and May, B. 1982b. Genetic relatedness and its application in selective breeding of Agaricus brunnescens. Mycologia 74:569-575.
33. Selander, R. K., Smith, M. H., Yang, S. Y., Johnson, W. E., and Gentry, J. B. 1971. IV. Biochemical polymorphism and systematics in the genus Peromyscus. I. Variation in the old-field mouse (Peromyscus polionotus). Univ. Texas Publ. 103:49-90.
34. Shannon, M. C., Ballal, S. K., and Harris, J. W. 1973. Starch gel electrophoresis of enzymes from nine species of Polyporus. Am. J. Bot. 60:96-100.
35. Shaw, C. R., and Prasad, R. 1970. Starch gel electrophoresis of enzymes - a compilation of recipes. Biochem. Genet. 4:297-320.
36. Shecter, Y. (ed). 1973. Symposium on the use of electrophoresis in the taxonomy of algae and fungi. Bull. Torrey Bot. Club 100:253-312.
37. Siciliano, M. J., and Shaw, C. R. 1976. Separation and visualization of enzymes of gels. In: I. Smith (ed.). Chromatographic and Electrophoretic Techniques, Vol. 2, Zone Electrophoresis. A. W. Heinemann Medical Books. London. 185-209 pp.
38. Spieth, P. T. 1975. Population genetics of allozyme variation in Neurospora intermedia. Genetics 80:785-805.
39. Steiner, W. W. M., and Joslyn, D. J. 1979. Electrophoretic techniques for the genetic study of mosquitoes. Mosquito News 39:35-53.
40. Tooley, P. W., Fry, W. E., and Villarreal Gonzalez, M. J. 1985. Isozyme characterization of sexual and asexual Phytophthora infestans populations. J. Hered. 76:431-435.
41. Werth, C. R. 1985. Implementing an isozyme laboratory at a field station. Va. J. Sci. 36:53-76.

42. Wheeler, L. L. 1972. XVI. Inheritance of allozymes in subspecific F_1 hybrids of Mus musculus from Denmark. Stud. Genet. 7:319-325.
43. Yang, S. Y., Wheeler, L. L., and Bock, I. R. 1972. IX. Isozyme variations and phylogenetic relationships in the Drosophila bipectinata species complex. Stud. Genet. 7:213-227.

APPENDIX I. Enzymes resolving to produce interpretable results by starch gel electrophoresis in selected fungi.

	AAT	AC	ACP	ADH	AGP	AGS	AK	AKP	ALD	DIA	EST	FDP	FUM	GAM	GAPDH	GDH	GK	B-GLU	GPI	GPT	GR	G6PDH	IDH	LAP	LDH	MADH	MDH	ME	MPI	NP	ODH	PEP-GL	PEP-LA	PEP-LLL	PEP-PAP	PGD	PGK	PGM	SD4	SOD	TPI	XDH
Ascomycetes																																										
** *Endothia paracitica*, *E. gyrosa* and *Cryphonectria* sp.				X								X			X	X		X	X	X	X	X			X	X	X	X	X					X	X							X
Basidiomycetes																																										
Agarics																																										
Agaricus campestris, *A. brunnescens* and *Lantinus edodes* (21, 22, 31, 32)	X			X						X			X		X		X		X	X				X		X	X	X	X			X		X		X	X			X		
Rusts																																										
* *Phakopsora pachyrhizi*	X	X	X						X	X	X					X			X		X	X		X			X	X	X			X	X	X	X	X					X	X
* *Puccinia carthami*, *P. carduorum* and *P. cardui-pycnocephali*			X								X		X		X	X	X		X		X	X			X		X	X	X	X		X	X	X				X				
Puccinia graminis and *P. recondita* (6)	X	X	X	X				X	X		X		X					X	X	X		X	X	X	X		X	X							X	X			X		X	

Continued on next page

	AAT	AC	ACP	ADH	AGP	AGS	AK	AKP	ALD	DIA	EST	FDP	FUM	GAM	GAPDH	GDH	GK	B-GLU	GPI	GPT	GR	G6PDH	IDH	LAP	LDH	MADH	MDH	ME	MPI	NP	ODH	PEP-GL	PEP-LA	PEP-LLL	PEP-PAP	PGD	PGK	PGM	SD4	SOD	TPI	XDH
Smuts																																										
* Sphacelotheca reiliana				X									X		X	X	X		X			X			X	X	X		X	X		X	X	X		X						X
* Tilletia caries, T. controversa and T. foetida		X	X					X		X	X					X			X		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X		X	X	X
* Tilletia indica and Neovossia horrida (2)		X	X				X	X		X	X			X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X
* Ustilago scitaminea		X					X		X					X		X	X		X			X		X		X	X				X			X	X				X		X	X
Imperfect fungi																																										
* Colletotrichum spp.	X	X	X		X		X			X	X		X		X	X	X		X	X	X	X	X			X	X	X	X	X					X	X		X	X		X	X
* Pyricularia oryzae	X	X			X	X	X			X	X		X		X	X			X	X	X	X	X			X	X	X				X						X	X		X	
Oomycetes																																										
** Bremia lactucae																X			X		X	X	X				X	X		X				X	X	X						
* Peronosclerospora spp. (3)	X	X	X		X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X			X	X	X	X	X		X		X	X	X
*** Peronospora tabacina		X	X		X	X					X					X		X	X	X	X	X	X		X		X	X	X	X		X		X		X				X		
Phytophthora infestans (40)								X		X			X				X	X	X		X		X		X	X	X	X	X					X	X	X				X		X

* Bonde et al., unpublished

** Micales et al., unpublished

*** Moss et al., manuscript in preparation

Appendix II: Buffer systems commonly used in electrophoresis.

Many different electrophoretic buffer systems have been published; only a few are presented here. Buffers routinely used in the Foreign Disease-Weed Science Research Unit are indicated. Formulas for additional buffer systems can be found in: Selander et al. (33), Werth (41), Shaw and Prasad (35), Cheliak and Pitel (7), Siciliano and Shaw (37), and Conkle et al. (10).

Sample buffer for protein extraction - 0.05 M Tris-Cl buffer, pH = 7.1.

Ridgway (29) buffer, pH 8.5/8.1:

Gel stock solution, pH 8.5	Electrode buffer, pH 8.1
0.030 M Tris	0.06 M Lithium hydroxide
0.005 M Citric acid	0.30 M Boric acid

Gel buffer made with 99% gel stock solution and 1% electrode buffer. Run at 250 V; 75 mA

Clayton and Tretiak (8) morpholine buffer, pH 6.1

Gel buffer	Electrode buffer
Dilute electrode buffer 1:10	0.04 M Citric acid, titrated to pH 6.1 with N-3(3-aminopropyl)-morpholine.

Run at 200 V; 90 mA

Cheliak (7) buffer, pH 7.0/7.0

Gel buffer, pH 7.0	Electrode buffer, pH 7.0
0.05 M histidine-HCl	0.125 M Tris
0.0014 EDTA	(pH 7.0 with 1.0 M citric acid)
(pH 7.0 with 1.0 M Tris)	

Run at 50 mA; 3 hrs

Steiner (39) buffer, pH 8.4/8.1

Gel buffer, pH 8.4	Electrode buffer, pH 8.1
0.074 M Tris	1.37 M Tris
0.009 M citric acid	0.314 M citric acid
	Dilute cathode tray 1:3
	Dilute anode tray 1:4

Run at 90 mA - 3 hrs

May's (19) modification of Selander's buffer, pH 6.3/6.7

Gel buffer, pH 6.7	Electrode buffer, pH 6.3
0.006 M Tris	0.068 M Tris
0.003 M Citric acid	0.037 M Citric acid

Run at 250 V; 75 mA.

May's (19) modification of Markert and Faulhaber's buffer (18), pH 8.7

Gel buffer	Electrode buffer, pH 8.7
Dilute electrode buffer 1:4	0.180 M Tris
	0.100 M Boric acid
	0.004 M Disodium EDTA

Run at 275 V; 70 mA

Appendix III: Enzyme systems commonly studied in electrophoresis: principal metabolic roles, E. C. numbers, abbreviations and staining recipes.[a]

Enzyme and Metabolic Role	E.C. No.	Abbrev.	MTT/PMS[b]	Cofactor[c]	Stain recipe[d]
Acid phosphatase Hydrolysis of phosphate esters	3.1.3.2	ACP	-	-	100 mg alpha-naphthyl acid phosphate 50 mg Fast garnet GBC salt 0.02 M monobasic phosphate buffer
Aconitase TCA cycle	4.2.1.3	AC	+	NADP	75 mg aconitic acid 4 units (u) IDH
Adenylate kinase Phosphorylation of AMP	2.7.4.3	AK	+	NADP	Agar overlay 200 mg glucose 100 mg ADP 60 u G6PDH
Alcohol dehydrogenase Glycolysis	1.1.1.1	ADH	+	NAD	1 ml ethanol
Alkaline phosphatase Hydolysis of phosphate esters	3.1.3.1	AKP	-	-	100 mg beta-naphthyl acid phosphate 50 mg Fast garnet GBC salt

Enzyme and Metabolic Role	E.C. No.	Abbrev.	MTT/PMS[b]	Cofactor[c]	Stain recipe[d]
Aspartate aminotransferase Degradation of amino acids	2.6.1.1	AAT	-	-	50 ml AAT buffer: 0.75 g alpha-ketoglutarate 2.75 g L-aspartate 1.0 g EDTA 10.0 g PVP40 15.0 g NaH_2PO4 15.0 g Na_2HPO4 1 liter dHOH 1.0 g Fast garnet GBC salt 200 mg Fast blue BB salt Pour on gel; wait 15 sec and pour off gel. Cover gel with plastic wrap and incubate at 37° C.
Diaphorase TCA cycle	1.6.4.3	DIA	-	NADH	2 mg 2,6-dichlorophenol-indolphenol 10 mg MTT
Esterase (15) Hydrolysis of carboxylic ester bonds	3.1.1.1	EST	-	-	Fluorescent 10 mg 4-methylumbelliferyl acetate

Enzyme and Metabolic Role	E.C. No.	Abbrev.	MTT/PMS[b]	Cofactor[c]	Stain recipe[d]
Esterase (15) - Cont'd					(dissolved in a few drops of acetone) 20 ml 0.1 M phosphate buffer (pH = 6.5)
Fructose bisphosphatase Gluconeogenesis	3.1.3.11	FDP	+	NADP	40 mg fructose-1,6-diphosphate 100 u PGI 60 u G6PDH
Fructose bisphosphate aldolase Glycolysis	4.1.2.13	ALD	+	NAD	100 mg fructose-1,6-diphosphate 100 mg arsenic acid 100 u glyceraldehyde-3-phosphate dehydrogenase
Fumarase TCA cycle	4.2.1.2	FUM	+	NAD	400 mg fumaric acid 100 u MDH
Galactosaminidase Carbohydrate metabolism	3.2.1.53	GAM	-	-	Fluorescent 10 ml mono or dibasic phosphate buffer 20 mg 4-methylumbelliferyl-N-acetyl-B-D-galactosaminide

Enzyme and Metabolic Role	E.C. No.	Abbrev.	MTT/PMS[b]	Cofactor[c]	Stain recipe[d]
Glucokinase Glycolysis	2.7.1.2	GK	+	NADP	90 mg glucose 50 mg ATP 60 u G6PDH
α-D-Glucosidase Degradation of glycogen	3.2.1.20	AGS	-	-	Fluorescent 10 mg 4-methylumbelliferyl-alpha-D-glucoside 15 ml 0.2 M sodium acetate buffer, pH 5.5. Flood gel; let sit 1 hr; flood with 0.2 M sodium carbonate buffer pH 10.0
β-D-Glucosidase	3.2.1.21	β-GLU	-	-	Fluorescent 75 mg 4-methylumbelliferyl-β-D-glucoside
Glucose-6-phosphate dehydrogenase Calvin cycle	1.1.1.49	G6PDH	+	NADP	400 mg glucose-6-phosphate
Glucose phosphate isomerase	5.3.1.9	GPI	+	NADP	Agar overlay 50 mg fructose-6-

Enzyme and Metabolic Role	E.C. No.	Abbrev.	MTT/PMS[b]	Cofactor[c]	Stain recipe[d]
Glucose phosphate isomerase - Cont'd Glycolysis					phosphate 60 u G6PDH
Glutamate dehydrogenase Biosynthesis and degradation of amino acids	1.4.1.3	GDH	+	NADP	2 g glutamic acid
Glutamic pyruvate transaminase Oxidative degradation of amino acids	2.6.1.2	GPT	-	NADH	Fluorescent 20 ml GPT buffer: 18.0 g DL-alanine 1.9 g alpha-ketoglutarate pH 7.6 with 1 M Tris q.v. 1 l dHOH 100 u LDH
Glutathione reductase Biosynthesis of lipids	1.6.4.2	GR	-	NADPH	50 mg glutathione 10 mg MTT 1 mg 2,6-dichlorophenolindolphenol
Glyceraldehyde-3-phosphate dehydrogenase Glycolysis	1.2.1.12	GAPDH	+	NAD	55 mg fructose-1,6-diphosphate 100 u aldolase 150 mg arsenic acid

Enzyme and Metabolic Role	E.C. No.	Abbrev.	MTT/PMS[b]	Cofactor[c]	Stain recipe[d]
α-Glycerophosphate dehydrogenase Glycerol phosphate shunt	1.1.1.8	AGP	+	NAD	300 mg alpha-glycerophosphate
Isocitrate dehydrogenase TCA cycle	1.1.1.42	IDH	+	NADP	75 mg isocitrate
Lactate dehydrogenase Glycolysis	1.1.1.27	LDH	+	NAD	10 ml 0.5 M lactate
Leucine aminopeptidase Degradation of amino acids	3.4.11.1	LAP	-	-	100 ml 0.5 M Tris-Cl, pH 7.0 20 mg L-leucyl-ß-naphthylamine 50 mg Fast garnet GBC salt
Malate dehydrogenase TCA cycle Oxidative phosphorylation	1.1.1.37	MDH	+	NAD	15 ml 0.5 M malate (pH 7.0): 33.5 g DL-malic acid 51.7 g Sodium bicarbonate 500 ml dHOH
Malic enzyme TCA cycle	1.1.1.40	ME	+	NADP	10 ml 0.5 M malate

Enzyme and Metabolic Role	E.C. No.	Abbrev.	MTT/PMS[b]	Cofactor[c]	Stain recipe[d]
Mannitol dehydrogenase Glycolysis	1.1.1.67	MADH	+	NADP	100 mg mannitol
Mannose phosphate isomerase Glycolysis	5.3.1.8	MPI	+	NADP	35 mg mannose-6-phosphate 60 u G6PDH 100 u PGI
NADH dehydrogenase (quinone) (Menadione reductase) Oxidation/reduction reactions	1.6.99.2	MNR	+	NADH	20 mg menadione
NADPH dehydrogenase Oxidation/reduction reactions	1.6.99.1	NADPHDH	+	-	20 mg NADPH
Octanol dehydrogenase Carbohydrate metabolism	1.1.1.73	ODH	+	NAD	1 ml 2-octanol Heat substrate before adding other ingredients or place at 37° C before staining
Peptidase: Peptide hydrolysis	3.4.11 or	PEP-GL PEP-LLL	- -	- -	Agar overlay 50 mg substrate:

Enzyme and Metabolic Role	E.C. No.	Abbrev.	MTT/PMS[b]	Cofactor[c]	Stain recipe[d]
Peptidase: Cont'd	3.4.13	PEP-PAP PEP-LA			glycyl-leucine, leucyl-leucyl-leucine, phenylalanyl-proline, or leucyl-alanine 20 mg peroxidase 5 mg rattlesnake venom 15 mg o-dianisidine
Phosphoglucomutase Glycogen and starch degradation Sucrose formation	2.7.5.1	PGM	+	NADP	100 mg glucose-1-phosphate 60 u G6PDH 10 u glucose-1,6-diphosphate
Phosphogluconate dehydrogenase Hexose monophosphate shunt	1.1.1.44	PGD	+	NADP	80 mg 6-phosphogluconate
Phosphoglycerate kinase Calvin cycle ATP generation Glycolysis	2.7.2.3	PGK	-	NADH	Fluorescent 20 mg 3-phosphoglycerate 20 mg ATP 10 mg $MgCl_2$ 100 u glyceraldehyde-phosphate-dehydro-

Enzyme and Metabolic Role	E.C. No.	Abbrev.	MTT/PMS[b]	Cofactor[c]	Stain recipe[d]
Phosphoglycerate kinase - Cont'd					genase
Purine nucleoside phosphorylase Salvage of purines	2.4.2.1	NP	+	-	200 mg inosine 200 mg arsenic acid 4 u xanthine oxidase 0.1 M phosphate buffer, pH 7.0
Superoxide dismutase Inactivates superoxide radicals	1.15.11	SOD	-	-	20 mg MTT 3 mg PMS 1 mg riboflavin
Triose phosphate isomerase Calvin cycle Glycolysis	5.3.1.1	TPI	+	-	2 g alpha-glycerophosphate 1.1 g pyruvate 100 u AGP 100 u LDH 20 mg NAD Incubate in 100 ml R gel buffer for 2 h at 37° C. Decrease pH to 2.0 with 1 N HCl. Increase to pH 7.0 with 1 M Tris and add:

Enzyme and Metabolic Role	E.C. No.	Abbrev.	MTT/PMS[b]	Cofactor[c]	Stain recipe[d]
Triose phosphate isomerase - Cont'd					250 mg arsenic acid 100 u glyceraldehyde-3-phosphate dehydrogenase 20 mg NAD
Xanthine dehydrogenase Purine metabolism	1.2.1.37	XDH	+	NAD	20 mg hypoxanthine Heat in R gel buffer until dissolved. Do not boil. Cool to room temperature before adding NAD, MTT and PMS.

---

[a] Staining formulas adapted from May (personal communication) unless otherwise noted.

[b] "+" indicates addition of 10 mg MTT and 3 mg PMS to staining solution. "-" indicates MTT and PMS not added to staining solution unless otherwise indicated.

[c] Cofactor added where indicated at following levels: 15 mg NAD, 10 mg NADP, 20 mg NADH, or 20 mg NADPH. "-" indicates that no cofactor is required.

[d] All stains mixed in 100 ml Ridgway gel buffer (29) unless otherwise indicated. Stains described as "agar overlay" mixed in 10-20 ml Ridgway gel buffer and 20 ml 8% hot agar. Stains described as "fluorescent" mixed in 10 ml Ridgway gel buffer; staining solution poured in thin layer over gel. Gels are placed on glass plates for agar overlays and fluorescent stains; gels placed in styrofoam trays for all other stains.

MYCOTAXON

Vol. XXVII, pp. 451-497 October-December 1986

THE LICHEN FLORA OF THE GALÁPAGOS ISLANDS, ECUADOR

WILLIAM A. WEBER

University of Colorado Museum
Campus Box 218, Boulder, CO 80309, USA

SUMMARY

196 species of lichens are reported for the Galápagos Islands, of which eleven, or five per cent, are believed to be endemic. One new species, *Stereocaulon azulense* Yoshimura & Weber, a close relative of the Beringian Arctic *S. wrightii* Tuck. and *S. apocalyptum* Nyl., is proposed, and one new combination, *Buellia mamillana*, is made for *B. glaziouana*.

The Galápagos Islands need no introduction. The visit of Charles Darwin and the *H.M.S. Beagle* in 1835 was integral to the development of modern understanding of speciation and evolution, and Galápagos is its showcase. Countless tourists know the area first-hand through the development of the National Park system of Ecuador and the Charles Darwin Research Station on Isla Santa Cruz. Many popular and semipopular books have been written about the flora and fauna, and television has brought the islands into every home and schoolroom.

A vascular flora of the islands (Wiggins & Porter 1971) provided a modern base for research which has stimulated many continuing studies of taxonomy and ecology. Gradstein & Weber (1982) discussed the plant geography of the bryophytes, and Weber (1976) published an updated catalog of the mosses. Introductory outlines of the lichen flora have been provided for general readers (Weber, Gradstein *et al* 1977) and for Spanish-speaking students (Weber & Lanier 1977). Weber & Beck (1986) discuss the effects on cryptogamic vegetation of the 1982-1983 El Niño phenomenon.

Contribution No. 397 of the Charles Darwin Foundation

An excellent description of the islands, their vegetation, and the history of botanical exploration, including all of the expeditions upon which lichens were collected, is available in Wiggins & Porter (1971, pp. 1-45) and need not be repeated here.

The most recent comprehensive taxonomic account of the lichens of the Galápagos Islands was Weber (1966). Because of an imposed editorial constraint, it could include only a historical list of lichens reported from the islands before the Galápagos International Scientific Expedition of 1964 took place. All published records were accounted for, but not all of the specimens of record had been examined for verification purposes. Since that time, a short paper describing novelties (Weber 1971) and the publication of records through issuance of the *Lichenes Exsiccati COLO*, summarized by Weber (1981), have augmented the original list. Popular accounts of the lichens were published also (Weber *et al.*, 1977, 1982).

I have made six collecting trips to the islands, and while many species remain unidentified, it is desirable to bring our knowledge of the lichen flora up to date. A number of significant reports are contributed here based on the collections on Isla Santiago by Larry Pike during expeditions sponsored by the University of Oregon. Incidental collections were made by various scientists visiting islands during the GISP expedition. These include Yale Dawson, David Cavagnaro, and Syuzo Itow. During my subsequent expeditions, I have been aided in the field by my students, Hans Beck, Jeannine Lanier, Claudia Rector and Lynn Riedel. The expedition of 1975 was a joint bryological-lichenological study with my colleagues S. Rob Gradstein and Harrie Sipman, University of Utrecht, supported by a grant from the National Geographic Society (Weber 1984a). I am indebted to my friend Tui De Roy Moore for her occasional and often vital help in locating rare species.

Santa Cruz Island is probably the richest area for lichen observations because of its well-developed vegetational zonation and its accessibility. Coastal rocks near Academy Bay are abundantly covered by lichens. These are best developed where the rocks are sloping or vertical so as to escape constant heating and to intercept fog. Coastal shrubs support large populations of *Ramalina* and *Roccella babingtonii*, while mangroves support a few colorful crustose types. Smooth-barked trees such as *Bursera*, *Pisonia* and *Piscidia*, as well as the trunks of *Jasminocereus* and the pads of *Opuntia*, provide excellent lichen substrates. The many cultivated and escaped exotic trees of the cultivated zone, as well as native species of *Scalesia*, provide excellent substrates for lichens. Living fences of *Jatropha curcas* in the farming area have a wide assortment of lichens, although most of these shrubs were destroyed during the 1982 El Niño. The shrubs of the *Miconia* zone and the summit *Scalesia* forests are the best places for large foliose lichens (*Sticta* and *Pseudocyphellaria*). The summit cinder cones support *Stereocaulon* species. The summit "grassland", dominated in fact by Cyperaceae, supports clumps of *Cladina*, *Cladia*, and many taxa of "*Parmelia*" in the broad sense.

Most of my intensive collecting was done within a day's walk from the Darwin Station. Other islands on which I myself have collected lichens are Champion, Española, Fernandina, Floreana, Isabela, Rábida, Santa Fé, and San Salvador. I am indebted to Forrest Nelson for his logistical support, and to the Charles Darwin Station for arranging for fishing boats, and, in 1984, our circumnavigation of Isabela and Fernandina islands aboard the Beagle IV, during which my party assisted Carlos Valle in his census of Galápagos Penguins and Flightless Cormorants. We appreciated Carlos' companionship and help to us during our climb of Cerro Azul.

I also must acknowledge the help, great and small, given us by the our resident friends who provided food and shelter or led us to springs and special lichen localities: André and Jacqueline De Roy and their daughter Tui; Mrs. Horneman and her son Siegvard; Alf Kastdalen, whose knowledge of the local plants was unsurpassed (Alf was accidentally electrocuted during a storm in 1982); several children of Carl Angermeyer; and Mrs. Margaret Wittmer of Floreana. Finally, I appreciated the companionship in the field of Dr. Ira Wiggins when the two of us decided, in 1964, to work Santa Cruz on foot rather than to gamble and possibly waste much time jockeying for space and time on side trips elsewhere.

HISTORY OF COLLECTIONS

Slevin (1959) provides an account of the history of exploration of the Galápagos Islands. While incomplete, his "selected" bibliography lists most of the pertinent published papers. If Hugh Cuming or David Douglas collected any lichens on Galápagos, they were probably large fruticose types which were gathered along with vascular plants. Hooker (1846) listed three lichens collected by Darwin on San Salvador (Santiago or James Island): *Usnea plicata* (probably *Ramalina usnea*, a pendent lichen which Darwin felt constituted a major element in the food of tortoises), *Borrera* (=*Heterodermia*) *leucomelos*, and *Sticta* (=*Pseudocyphellaria*) *aurata*. Farlow (1902) contributed a short lichen list in Robinson's flora. Some of the earliest, and most dubious, collections in the record are those made by a Rev. T. Hill (the chaplain?), on the Agazziz expedition of the Museum of Comparative Zoology, Harvard University, in 1873, aboard the U. S. Coast and Geodetic Survey steamer "*Hassler*". The expedition spent only nine days anchored at James Bay on Isla Santiago, few specimens were gathered and collection data were minimal. In fact, a number of specimens marked "Galápagos" belong to species endemic to the southern coast of South America. The rock substrates on which they occur are not volcanic, and for practical purposes most of these should be ignored, except for the fact that a few new species were based on them. Their type localities may remain forever unknown.

Previous to the Galápagos International Scientific Expedition of 1964 (Bowman, ed. 1966), only one lichen student had visited the island: Albert W. C. T. Herre, who landed in January, 1929 at Post-Office Bay on Floreana and at Academy Bay on Santa Cruz, making a few casual lichen collections. Being an amateur lichenologist as well as a professional ichthyologist, his collections, though few, were out of the ordinary, yielding a few undescribed species and one notable disjunction. Most collections had been made casually by scientists of other disciplines. For example, in 1898, Edmund Heller and Robert E. Snodgrass, zoologists of Stanford University aboard the schooner "Julia E. Whalen", collected animals and plants, some of which were lichens, from December to the following June.

Serious lichenology began on Galápagos with the expedition of the California Academy of Sciences, 1905-1906. The botanist of the expedition was Alban Stewart, an instructor in Botany at the University of Wisconsin. His lichens were named by W. G. Farlow and are housed at the Farlow Herbarium, Harvard University. Stewart's own words give some indication of the extent to which he involved himself with lichens. "I am not a lichenologist in any sense of the word, and it is with some hesitation that I approach a subject with which I have so little acquaintance. However, as I made a number of notes on the subject while collecting there, and as very little has been written on the general distribution etc. of the Lichenes of these islands, it seems worth while to publish these notes, along with a list of the species which were secured."

"This list is probably far from complete, for I was more interested in collecting and studying the distribution of the vascular plants; and it was often the case that lichens were carefully collected only where no vascular plants in good condition were to be found, as was sometimes the case when the lower islands were visited during the dry season. Notwithstanding the rather neglectful way in which this group of plants was treated, sixteen species were found which had not before been reported from the islands, and the range of quite a number of species already known was considerably extended. There were, however, some fifteen species, reported by former expeditions to the islands, which do not appear in my collection. Some of these have been taken but once."

One can read between the lines that, as is often the case, botany would be low in the peck order on an expedition dominated by zoologists intent upon collecting Galápagos land tortoises. Stewart might have been frustrated very often at being unable to stay in a rich botanical area when the zoologists had decided they had completed their work. With his major goals fixed on the vascular plants, we can only be grateful to him for devoting even a small portion of his time to collecting lichens.

Svenson (1963) decried the lack of attention given to lichens and singled them out as being in great need of study on the islands. Farlow (1902) had written: "Judged by the collections of previous expeditions as well as those of Messrs. Snodgrass and Heller, the lichen flora of the Galápagos Islands must be striking in appearance and abundant. Naturally the collections include principally the larger and more showy species of foliose and fruticulose habit, which are in most cases identical with species found along the Pacific Coast of America from California to Chile." Svenson (1935), describing Tower Island, says: "The trees...have swollen and twisted branches cluttered with white coralliform lichens." And Stewart (1912) wrote: "When one lands for the first time on almost any of the islands, one is immediately struck with the great abundance of lichens. This is true not only of the larger and higher islands, which reach sufficient elevation to receive a considerable amount of moisture from the fog-banks which strike their sides...but it is true also...of the lower islands... where...desert or semidesert conditions prevail."

In the winter of 1963, I was scheduled to make a trip into Baja California with Reid Moran, but he suggested that I get in touch with Bob Bowman, who was organizing what became the Galápagos International Scientific Expedition (GISP), a multidisciplinary scientific group planning to go to the Galápagos for several reasons: to dramatize the importance of the Galápagos as a unique scientific area from a biological and historical viewpoint as the birthplace of the theory of Natural Selection, to dedicate the new Darwin Research Station there, and through seminars, to explain to the people of Ecuador what a treasure they had and the necessity to preserve it for posterity.

When I called Bowman and asked if they had planned to take along a cryptogamic botanist he retorted, "No, should we?". Fortunately, he was very easy to convince, and so began the first visit to the islands by a lichenologist. I shall never forget my first impressions of the lichen flora. I had gleaned all of the published literature on the islands and found only a single illustration showing lichens--a cover of "*Life*" magazine showing a leaning manzanillo tree upon which the photographer had posed a land iguana. The bark of the tree appeared to have crustose lichens on it.

Upon landing at Puerta Ayora in Academy Bay I was detailed for a few hours to stand guard over the luggage, but at the first opportunity I walked a few hundred yards back of the Darwin Station into the cactus forest, which at that time did not have neat crushed coral walks and man-made walls. I was quite overwhelmed. Every rock, cactus pad and tree trunk seemed to be to be totally covered with white and varicolored foliose and crustose lichens, and I sat down and almost wept because I felt that I couldn't possibly get on top of this fantastic lichen flora in the six weeks at my disposal. Bob Usinger, in his autobiography (1972) came away with a slightly different impression of my feelings, writing: "[Weber] came in from his first day of field work like a small boy from a candy shop."

I feel very fortunate that, since 1964, I have been able to revisit the islands five times, sometimes leading student tours, and sometimes on collecting trips. I have been able to collect the majority of the obvious species and some of the cryptic ones. Nevertheless, as in any area, the real floristic picture will only emerge when a well-trained and acutely perceptive resident lichenologist spends extended periods on all the islands, and when enough monographic work has been accomplished to make possible the identification of the difficult groups. I sincerely hope that this will be accomplished through an Ecuadorean botanist-in-residence.

A general description of the lichen vegetation is not given here because I have developed it elsewhere (Weber & Gradstein, *ibid.*). Some observations should be made concerning endemism in general and inter-island endemism. In the vascular plants, inter-island endemism is quite important. In the lichens I believe that a given lichen species will be present on any island which meets its ecological requirements, and that there is no evidence that natural selection has operated to produce special island races or species.

Significant Galápagos endemism occurs in the lichen flora, nevertheless. This is most apparent in the crustose and fruticose lichens inhabiting the coastal rocks. There are endemic species, often with close relatives on the coast of Chile, and there are a few disjunct species involving Galápagos and mainland patterns. The lichens growing on the bark of trees tend to belong to more widely distributed Neotropical species, and only a few taxa in the highest reaches of the largest islands are Andean. I have developed this discussion elsewhere (Weber & Gradstein, *ibid.*).

I did not realize until my expedition of 1983 (Weber & Beck 1986) what a devastating effect the extremely high rainfall of the record El Niño event might have on lichens, when running fresh water flowed over the coastal rocks for many days at a time, leaching pigments and scouring the cortices of crustose lichens so that they became indistinguishable, waterlogging the foliose and fruticose lichens so that they fell from the trees in masses, and saturating the ground and the bark of trees, resulting in catastrophic losses of habitats.

In this connection, Hale (1984), based on studies of the flooding of a fresh-water stream in Florida, found that some corticolous lichens are killed by submergence of a few days. Santesson (1939) suggested that one to two weeks of submergence was a likely minimum for lacustrine saxicolous lichens in Sweden. During the Great El Niño there was a combination of submergence in salt water caused by prolonged abnormal high tides and prolonged fresh-water runoff. Even on elevated ground the lichen cover of rocks was leached and decorticated.

Hamann (1986) noted a depression in a lava field on Santa Fé Island several years before the Great Niño which was bordered by a prominent upper line of saxicolous lichens. It occurred to him that at some previous period this depression must have been a lake below the highest level of which all lichen growth had been destroyed. His assumption was correct, for the lake was refilled in 1983!

The ancient high water line of the pluvial period (about 11,000 years ago) in the Great Basin of the western United

States at Lake Lahontan, Nevada, is marked by a prominent high water lichen line of *Acarospora chlorophana*. Recovery of the lichen cover below this level is insignificant although the thriving lichens above the ancient water level can be seen from several miles distant.

I anticipate that the lichen flora of the Galápagos will eventually recover, but I expect many decades to elapse before we will see again the luxuriant lichen tapestry that covered the islands in 1964.

SCOPE OF THE CATALOG

The catalog lists 196 lichen species that are reasonably correctly identified up to the present moment. Previous reports have been investigated and the cited specimens, in most instances, were located and evaluated. Old names have been brought up to date. New reports for the Galápagos Islands are signaled by an asterisk. All specimens cited, except as otherwise noted, are in Herbarium COLO, Boulder; the cited number in all instances is that of the COLO lichen accession book. When reports are few and from one island, citations are given. When numerous collections were made and the taxon is not a critical one, only one or a few specimens are cited and only the names of islands are given. All numbers distributed in *Lich. Exs COLO* are cited. Collections examined at other institutions are listed under collector's number and herbarium acronym. Complete citations of species names are given only when the name is not easily available in Zahlbruckner's *Catalogus Lichenum Universalis*.

The name of the lichen is followed by the collection records, and a brief statement of the habitat, substrate, and relative abundance. Very brief statements concerning recognition are given for the more easily recognized species; they are not intended to be exhaustive, but are only provided to enable visitors to Galápagos, who cannot obtain collection permits, to be able to identify some of the more conspicuous species in the field. Characteristics only visible by compound microscopy are omitted. Specialists should refer to the original literature and to the specimens distributed in *Lichenes Exsiccati COLO*.

A significant part of the collections remains unidentified, not because they are undescribed species but because the literature and collections of Neotropical lichens, especially crustose forms, are scattered and the specimens need to be compared with type specimens in European herbaria or require the attention of monographers. The families Arthoniaceae and Graphidaceae, and genera such as *Buellia* and *Bacidia* loom large in this category. Any of these groups will be made freely available on loan upon request of the monographer.

Appendix I deals with synonyms, misidentifications and misapplied names found in the earlier published reports. Appendix II presents new combinations. Appendix III contains descriptions of new taxa.

ENDEMIC TAXA

Eleven species are now thought to be Galápagos endemics: *Arthonia platyspilea*, *Arthothelium galapagense*, *Bacidia insularis*, *Buellia galapagona*, *B. straminea*, *Lecanora pseudopinguis*, *Pertusaria albinea*, *Physcia insularis*, *Roccella galapagoënsis*, *Stereocaulon azulense*, *S. weberi*. The four corticolous species, however, probably will be found on the mainland. In any event, the endemism is extremely low, constituting only five per cent or less, of the known flora.

SPECIES LIST

Note: Names of islands conform to the alternatives chosen by Wiggins & Porter (1971, end-papers map).

***Acarospora schleicheri** (Ach.) Mass.

Rabida: *40100*; Santa Cruz, *54819*. Infrequent or rare on lava rocks, particularly those with a sandstone-like texture. Especially well-developed on Rabida. This is a form with small angular areoles.

***Anthracothecium leucostomum** (Ach.) Malme.

P. libricola Fée, Essai, p. 82. 1837. Santa Cruz, *Weber 40199, 41111, 40193, 40255, 40258*, abundant on living fences of *Jatropha curcas*. Most *Jatropha* fences on Santa Cruz were destroyed during the Great Niño. San Salvador: *Pike 56180* (on *Acacia rorudiana*). Evidently closely related or identical to *A. pyrenuloides* (Mont.) Müll.-Arg.

Anthracothecium ochraceoflavum (Nyl.) Willey.

Floreana, Genovesa, Fernandina, San Salvador, Santa Cruz, Santa Fé, Tower, Wenman. A common crustose lichen making conspicuous yellow splotches on smooth-barked trees such as *Bursera*, *Laguncularia*, *Rhizophora* and *Hippomane*. Restricted to areas at sea level and close to tidal influence, extending to the transition zone in some places. The thallus is pale yellow-orange, with darker rust-orange perithecia (not to be confused with *Py-*

renula cerina, which has a deep red-orange thallus and almost invisible perithecia).

Arthonia platyspilea Nyl.
"Galápagos", *Hassler Expedition* (Willey 1890): Gardner: *Snodgrass & Heller* (Farlow 1902); San Salvador: *Pike 55200*, *55222*; Santa Cruz: *Lich. Exs. COLO 122*. Common on *Croton*, also found on *Bursera*. Stroma pale, irregular, "bruised-looking"; thallus IKI+ blue.

Arthonia tumidula (Ach.) Ach. *A. cinnabarina* (DC.) Wallr. *A. gregaria* (Weig.) Koerb.
Pinzon, San Cristóbal, Santa Cruz. Very common on smooth-barked trees at all altitudes. Recognized by the small round plane grayish or reddish stroma with red *Trentepohlia* algae "leaking out" around the margins or sometimes staining the entire disk or thallus red.

Arthothelium galapagoënse Huneck & Follmann.
Endemic. Plazas, San Salvador, Santa Cruz: *Lich. Exs. COLO 113*. A dominant crust on rocks just above the high tide mark, forming large white patches with irregular-shaped bluish-pruinose stromae. A counterpart of the Chilean coastal *A. spilomatoides* (Nyl.) Zahlbr.

***Aspidophyllum fugiens** (Fée) R. Sant.
Santa Cruz: on leaves of *Coffea*, Horneman garden, *40433*, !Vezda.

***Bacidia apiahica** (Müll.-Arg.) Zahlbr.
Santa Cruz: on leaves of *Miconia robinsoniana*, summit heath zone, *40216*, !Vezda.

Bacidia insularis Zahlbr.
Endemic, the type collected on Floreana, Post Office Bay, on *Bursera*, by Herre. Bartolomé, Plazas, Santa Cruz. Common on *Laguncularia*, *Castela*, *Bursera* (smooth-barked trees) on live bark and dead decorticated wood.

***Bacidia millegrana** (Tayl.) Zahlbr.
Pinta, Santa Cruz: *Lich. Exs. COLO 121*, San Salvador: Common on *Bursera* and *Piscidia* in the arid zone.

***Bacidia rubella** (Ehrh.) Mass. *B. luteola* (Schrad.) Mudd.
Santa Cruz: on *Jatropha curcas* living fence, Bella Vista, *41125*.

***Bacidia subleporina** (Nyl.) Zahlbr.
San Cristobal: on *Citrus* leaves below Tres Palos, *Lanier 63764* (in packet of *Tapellaria epiphylla*). !Vezda.

***Brigantiaea leucoxantha** (Spreng.) Sant. & Hafelln.
San Salvador: *Xanthoxylum* forest with *Psychotria* understory along trail from top of James Bay lava flow top the western peak, 530 msm., *Pike ID18-16*. !Hafellner.

***Buellia dejungens** (Nyl.) Vain.
Santa Cruz: on stone, barranca behind Darwin Station, *40838*. Thought to be endemic to the West Indies, according to Imshaug (1955).

***Buellia galapagona** W. A. Weber, The Bryologist 74:188. 1971.
Endemic. San Salvador: *Pike L-55431*; Santa Cruz: *Lich. Exs. COLO 344* (type), *40360*, *40872*. A dominant and conspicuous coastal rock lichen in association with *Lecanora pseudopinguis* and *Arthothelium galapagoënse*. Forming large tan-brown patches with large black apothecia.

***Buellia lauricassiae** (Fée) Müll.-Arg. See Imshaug (1951, p.112-114).
Santa Cruz: on *Bursera*, cactus forest, *40336*.

Buellia mamillana (Tuck.) W. A. Weber, **n. comb.** See Appendix II.
Darwin, San Salvador, Santa Cruz, Wolf. An abundant pale yellow or white crustose lichen growing on dry surfaces of horizontal lava blocks in the cactus forest. The thallus is minutely areolate, effuse, with small black or somewhat pruinose convex apothecia. Widespread in subtropical America.

***Buellia modesta** (Kremp.) Müll.-Arg. See Imshaug (1955a, p. 497).
Fernandina: 40463; Santa Cruz: *40061*, *40841*, *40859*, *41048*. On lava in the dry cactus forest and on coastal rocks. Imshaug deals with a corticolous plant, but Malme (1927) reports it in South America equally on rocks and trees.

***Buellia parasema** (Ach.) DeNot. See Imshaug (1951, p. 84-92).
San Salvador: On *Bursera*, 250 m.s.m., *Pike 56171*.

Buellia straminea Farlow *in* Robinson. See Imshaug (1955, p. 282-283).
Endemic. Bartolomé, Fernandina, Isabela, Pinta, Plazas, Rábida, San Salvador, Santa Cruz. While not a dominant or

conspicuous species, *B. straminea* is a constant on coastal rocks. The type material did not portray the variability of the species as I know it in nature, the yellow thallus being distinctly radiate-lobed when well-developed on hard lava but consisting of flecks and irregular lobulate areoles when pioneering, for example, on soft tufa. *Pyxine glebosa* Tuck., described from Galápagos and discussed by Imshaug (*l.c.*) can safely be placed in synonymy.

***Bulbothrix laevigatula** (Nyl.) Hale. *Parmelia laevigatula* Nyl.
San Cristóbal: Wreck Bay, *Itow 40982*; Santa Cruz: *40402.* !Hale. Thallus white, with bulbate marginal cilia, rounded sinuses, narrow lobes; surface isidiate, not maculate; cortex K+ yellow, med. K-, KC+ red (lecanoric).

***Byssoloma subdiscordans** (Nyl.) P. James.
Floreana: 64132; San Cristóbal: *Gradstein 63825 p.p.*; Santa Cruz: *Sipman 8*, *Weber 64131, 40247, 40248, 40250, 63479.* ! Vezda. On leaves of *Eugenia jambos*, zone of cultivation, with *Strigula*, *Porina*, *Sporopodium*, *Echinoplaca* and *Tapellaria.*

***Byssoloma tricholomum** (Mont.) R. Sant.
San Cristóbal: on citrus leaves below Tres Palos, *Lanier L-63764* (in packet with *Tapellaria epiphylla*). !Vezda.

***Caloplaca byrsonimae** (Malme) Zahlbr. *Callopisma byrsonimae* Malme, Ark. f. Bot. 20A(9):33.1926.
Santa Cruz: *40205*, *40585 (cum apo.)*, *40386*, *40451*, *40563.* San Salvador: *Pike 56169.* The type came from Matto Grosso, Brasil. This is a common and easily recognized lichem, usually a sterile, very thin orange-yellow crust covered with minute clustered cylindric isidia. The black prothallus is usually evident in good material. Apothecia are very sparse.

**Caloplaca camptidia* (Tuck.) Zahlbr.
San Salvador: *Pike 55221, 55205, 56168*; Santa Cruz: *40863.* Usually on trees, but on boulders at Academy Bay, Santa Cruz. Apothecia dark brown, with paler rim; epithecium K+ violet wash; spores 10-12x4-5m , polarilocular with wide isthmus.

***Caloplaca cirrochroa** (Ach.) Th. Fr.
Champion: *2781*; Santa Cruz: *40055.* On shore boulders just above the high tide mark east of Darwin station, on rock faces of the barranca behind the station. Thallus orange, lobate but lobes quite short and broad, erupting back from the tips with saucer-shaped bowls of yellow soredia; lobe tips somewhat thickened, often somewhat pruinose.

Caloplaca floridana (Tuck.) S. Tucker, Bryologist 82:132. 1979.
Lecanora floridana Tuck.

San Salvador: on *Bursera*, *Pike 56167*. The black-fruited corticolous *Caloplaca* species in all probability eventually will be segregated into new genera.

***Caloplaca isidiosa** (Vain.) Zahlbr., Cat. Lich. 3:241. 1931.
Placodium isidiosum Vain., Étude Lich. Brésil 18. 1890.

Darwin, Gardner, Genovesa, Pinta, Plazas, San Salvador, Santa Cruz, Wolf. Described from Brazil, but evidently the same taxon occurs on the Chilean coast and in South Africa. A common orange lichen of coastal rocks, characterized by a narrowly lobate thallus margin, with slender isidia on the older thallus parts. Previously reported by Dodge as *C. elegans*, *C. muelleri*, *C. rugulosa* (Nyl.) Zahlbr., and by Stewart (1912) as *Placodium murorum*.

***Chiodecton effusum** Fée.

Rábida: on *Croton*, *Cavagnaro 40459*.

***Chiodecton farinaceum** Fée.

Rábida: *40442*; San Salvador: *Pike 55411*; Santa Cruz: *40155*, *40157*, *40159*, *40424*, *40445*, *40610*. On *Laguncularia*, cacti, *Bursera*, coastal scrub to transition zone.

***Chiodecton myrticola** Fée.

Rábida: *40506*; San Salvador: *Pike 55432*; Santa Cruz: *40053*, *40607*. On *Piscidia* and *Bursera* in the cactus forest, up to 300 m.s.m on Rábida.

***Chrysothrix candelaris** (L.) Laundon. *Lepraria candelaris* (L.) Fr.

Floreana: on *Acacia rorudiana*, trail from Black Beach to highlands, *63018 p.p.* (with *Diploicea canescens*), Rábida, Wolf (on stones). A golden yellow sorediate crust forming large patches on bark and stones.

***Cladia aggregata** (Sw.) Nyl.

Santa Cruz: *55403*. In the summit grassland at foot of El Puntudo, forming large discrete rounded mounds 2-3 dm diameter. *Cladonia*-like, with tan to brown, varnished surface, richly dichotomous, with pointed branch tips; thallus with large perforations.

Cladina confusa (R. Sant.) Follm. & Ahti, Philippia 4:314. 1981. *Cladonia galapagosensis* Ahti; *C. polia* R. Sant.

Fernandina, Isabela, San Cristóbal, Santa Cruz: *Lich. Exs. COLO 105* (as *C. galapagosensis*), *106* (as *C. polia*). Forming large hemispherical mounts in the summit grassland, usually anchored by entanglement of the thallus with low shrubbery. There are strains with and without usnic acid. Branching is mostly anisotomic trichotomic. Reactions with K and Pd are negative.

***Cladina sandstedei** (des Abbayes) Ahti, Beih. Nova Hedw. 79:40. 1984. See also Ahti (1961).

Pinta: east slope at 490 m.s.m., much drier zone than summit sites for *Cladina*, among *Polypodium* on old lava flows, directly above *Opuntia* bushes, *Cavagnaro 68108*. Formerly considered to be endemic to the Caribbean area. Thallus gray, with the terminal ends blackening; branching anisotomic dichotomic; cortex K+ yellow, Pd+ orange.

***Cladonia balfourii** Crombie

Floreana: *62897*, *62988*; Isabela: *63523*; San Salvador: *Pike 56163*; Santa Cruz: *Lich. Exs. COLO 139*. !Thomson. Frequent on lava knolls with ferns and bryophytes, Transition zone. The *Cladonia chlorophaea* group is very difficult, especially in the tropics. *C. balfourii* is said to differ from *C. chlorophaea* by lacking cups or having very irregular ones. By this criterion our material could as well belong to *C. chlorophaea*.

Cladonia ceratophylla (Sw.) Spreng.

San Salvador, Santa Cruz. A handsome and easily recognized species with large, white, thin basal squamules, convolute when dry, with long sparse white cilia, no cups but rather acicular podetia. Common on dead wood and other decaying vegetation in the zone of cultivation and *Miconia* belt.

***Cladonia didyma** (Fée) Vain.

San Salvador: on shrubs, James Bay, *Pike 55241*, *55426*. Santa Cruz: summit grassland, *40784*. !Thomson. Common in the summit grassland, often in burned spots. Podetia decorticate and discoloring dark brown; granular sorediate, K+ yellow, Pd+ red; apothecia red.

***Cladonia macilenta** Hoffm. ssp. **theiophila** Asahina

Isabela: *63514*; Pinzón: *63571*; San Cristóbal: *63738*, *63754*; Santa Cruz: *63343*. !Thomson. On the ground in the summit fern-sedge zone. Podetia slender, tall, branched, ecorticate, coarsely sorediate, with large central cavity. Thomson says: "rather tall, but the chemistry of usnic and barbatic acids in GE and thamnolic in BaOH is quite diagnostic."

***Cladonia pityrea** (Flk.) Fries

Fernandina, Floreana, San Salvador, Santa Cruz, !Thomson. One of the common species of the forest floor, transition and moist zones.

***Cladonia sphacelata** Vainio

Santa Cruz: *63045*, *63049*. Fern-sedge zone, summit between El Puntudo and Cerro Crocker. !Thomson. Podetia slender, blackish, K-, Pd- (in the field I noted that this was greener and more corticate than 63044 which was growing with it (=*C. subsquamosa*).

***Cladonia** *cf.* **subcariosa** Nyl.

Santa Cruz: summit fern-sedge zone, on saddle between El Puntudo and Cerro Crocker, 700 m.s.m., *63339*. Thomson says: "although only sterile squamules, I am thinking of *C. subcariosa* Nyl. in the sense of Culberson (1969). The chemical contents, atranorin plus norstictic acid is not a common combination and with coarse squamules like this I feel fairly confident of the determination. Of course, if this turns out to be something with podetia of quite another kind I would have to revise the answer. Culberson mentions a Cuban specimen so this may be a tropical member of the *C. cariosa* group."

***Cladonia subsquamosa** (Nyl.) Vain.

Floreana: on *Psidium* branches between dense moss cushions, *Gradstein 62997*; Santa Cruz: El Puntudo, *63044*. !Thomson. Squamules small, delicate, sorediate, the podetia acicular, sorediate, little branched (63044 is ecorticate, esorediate with squamules on the podetia).

***Cladonia subulata** (L.) Wigg.

Isabela: Cerro Azul, S slope above Caleta Iguana, among fern-sedge vegetation, *Sipman 63520*. !Thomson.

***Cladonia symphoriza** Nyl.

Santa Cruz: saddle between E. Puntudo and Cerro Crocker, *63341* (previously known from Colombia. !Thomson. Podetia stout, squamulose, with terminal clusters of red apothecia. Mixed with *C. sphacelata* Vain.

***Coccocarpia palmicola** (Spreng.) Arvidsson & Galloway. See Arvidsson (1982).

Fernandina, Isabela, Santa Cruz, San Salvador. ! Arvidsson. Most common on trees, from lower Transition to moist zone, but occasionally on rocks. Thallus lead-gray with rounded lobes and blue-gray-black rhizines forming a brush below; central part of thallus with numerous erect cylindric isidia. Our material always sterile.

Coccocarpia erythroxyli (Spreng.) Swinscow & Krog. *C. pellita* var. *parmelioides* and *Pannaria molybdaea* of earlier reports.

Santa Cruz: *40290*; San Salvador: *Pike 2718*. !Arvidsson. Larger than *C. palmicola* and totally lacking isidia, usually fertile, with large black convex apothecia.

***Collema furfuraceum** (Arn.) DuRietz

Santa Cruz: *40207*, *54841*; San Salvador: *55428*. !Degelius. Common on *Bursera* at Academy Bay, near "The Cracks". Thallus foliose, black, with rounded thallus lobes, ridged-pustulate, with isidia on the ridges, but the thallus not obscured below the ridges. Always sterile.

Dictyonema montanum (Sw.) Parmasto *ex* Follmann. *Cora pavonia* (Sw.) Fr.

Santa Cruz. Common on naked or mossy trunks of trees and shrubs in the moist zone. A conspicuous foliose lichen resembling very thin and fragile shelf-fungi, with surface concentric arcs, the thalli often imbricate, white when dry, gray-green when moist. Hymenium yellowish-waxy, on the underside, of discontinuous plates or fragments.

Dictyonema guadelupense (Rabenh.) Zahlbr. *Dictyonema sericeum* of Howell (1942).

Isabela, San Cristóbal, San Salvador, Santa Cruz. Infrequent on trees in the moist zone, on *Miconia robinsoniana*. Thallus dark green, amorphous, with a "nap" of shaggy tan or whitish hyphal masses.

***Dimerella lutea** (Dicks.) Trev.

Santa Cruz: 5 mi E of Horneman Farm, on *Psidium galapageium*, *40480*.

***Diploicea canescens** (Dicks.) Mass. *Buellia canescens* deNot.

Floreana: on *Acacia rorudiana* bark, Black Beach trail to highlands, *63018 p.p.* (in packet of *Chrysothrix candelaris*).

***Diploschistes actinostomus** (Pers.) Zahlbr.

Santa Cruz: *40043*, *40105*, *40818*, *40825*, *40826*, *40870*. In frequent, on smooth, hard lava rocks along the shore and on talus blocks of the barranco near the Darwin Station.

***Diploschistes muscorum** (Scop.) R. Sant. *D. bryophilus* (Ehrh.) Zahlbr.
Isabela: on *Stereocaulon azulense*, Cerro Azul, *81068*.

***Diploschistes scruposus** (Schreb.) Norm.
Isabela, San Cristóbal, San Salvador. On soil and rocks.

***Dirinaria applanata** (Fée) Awasthi (previous reports of *Physcia picta* apply to this species).
Genovesa, Rábida, San Salvador, Santa Cruz. Abundant on twigs and trunks of smooth-barked trees. Thallus closely adnate with flat, flabellate, confluent and often longitudinally plicate lobes; soralia laminal, round; medulla white. Usually sterile.

Dirina approximata Zahlbr. *Dirina herrei* Zahlbr. See Tehlér (1983).
Floreana: Herre in Zahlbr., *Lich. Rar. Exs. 269* (Type of *D. herrei*), *Lich. Exs. COLO 367* (as *D. herrei*); Isabela, Pinta, Plazas, Rábida, San Salvador, South Seymour: Herre, *Krypt. Exs. Vindob. 3144* (Type). Abundant on *Bursera* trunks, cacti and shrubs, in the cactus forest; rarely on rock. This is not an endemic; we have collections from the adjacent mainland and from the West Indies.

***Dirinaria caesiopicta** (Nyl.) Awasthi, Bibl. Lich. 2:94. 1975.
Bartolomé, Bindloe, Floreana, Genovesa, Isabela, Plazas, (cited by Awasthi), San Salvador, Santa Cruz. Very common on coastal rocks.

***Dirinaria confluens** (Fr.) Awasthi, Bibl. Lich. 2:28-31. 1975. (Reports of *D. (Physcia) aegialita* apply here).
Floreana: *40604*; San Salvador: *Pike 56160*; Without locality: *Hassler Exped.* (FH, cited by Awasthi). Common on bark and twigs of *Bursera*. Thallus esorediate, with confluent and plicate lobes; hymenium 80-100m high (the critical difference between this and *D. subconfluens*).

***Dirinaria confusa** Awasthi, Bibl. Lich. 2:56-60. 1975.
Floreana, *Taylor 867* (FH, cited by Awasthi); Genovesa, *Stewart 356* (FH, cited by Awasthi); Rábida: *Stewart 357* [cited by Thomson (1963) as *Physcia aspera*]. "Easily distinguished by the characteristic irregularly thickened, simple to coralloid-branched crateriform sorediate isidia producing coarse granular soredia" (Awasthi, 1975). Very similar to D. confluens but having a lentiform hypothecium, lacking divaricatic acid and

said to have the thallus not adglutinated to the substrate.

***Dirinaria leopoldii** (Stein) Awasthi, Bibl. Lich. 2:89-91.
Española: *Itow 40736, 40762.* On branches of bushes. Similar to *D. applanata* but with red medulla.

***Endocarpon pusillum** Hedw.
San Salvador: on rock, above James Bay, 895 m.s.m., *Pike 55238.*

***Erioderma sorediatum** Galloway & Joergensen, Lichenologist 7: 139-142. 1975.
Fernandina: 2,000 ft. alt., *Snodgrass & Heller* (DS), a fragment 1 x 2 mm found in a packet with *Pseudocyphellaria aurata*; specimen has a portion of thallus with one apothecium; Santa Cruz: along trail from Bella Vista to Media Luna, in upper *Miconia* zone; on *Miconia* branchlets in opening near rivulet, 550 m.s.m., *Sipman L-21.* This is an example of the likelihood of continual discovery of isolated disjunct species with extremely small populations in the Galápagos. First described from New Zealand and reported from the Philippines (Galloway & Joergensen, l.c.), it is known now from Brazil (K. Kalb, *Lichenes Neotropici 321*), and Oregon (Lane Co.: on moss from on *Vaccinium membranaceum* in sand dunes, 30 ft. alt., behind Heceta Lodge, Florence, *Howe s n., COLO L-64494*). The thallus has bluish limbiform soralia on the upturned lobe edges; underside white with bundles of black rhizines.

***Everniastrum vexans** Hale, Mycotaxon 3:350. 1976. (*Parmelia americana*, *P. camtschadalis* of reports).
Isabela: *Lich. Exs. COLO 499*, !Hale; San Salvador, Santa Cruz. Locally abundant on twigs in humid areas in the highlands. Thalli elongate, involute, sparsely black-ciliate, white above, black and naked beneath.

***Glyphis cicatricosa** (Ach.) Zahlbr.
Floreana, Pinzón, San Salvador, Santa Cruz. A thin tan crust common on smooth bark (*Citrus*, *Scalesia*, *Croton*) in the moist zone. Very easily recognized. The fruiting area is discrete, almost circular, with many small closely fitting round or slightly lirelliform brown open disks.

***Graphina virginea** (Eschw. *in* Mart.) Müll.-Arg.
Santa Cruz: *Lich. Exs. COLO 646, 40024, Herre 41160, Itow 40733.* Forming large continuous white areas on bark of large avocado tree along fence line just above old Horneman property. Apothecia elongate, white, not raised.

***Graphis afzelii** Ach. For *Graphis* species, see Wirth & Hale, Contrib. U. S. Nat. Herb. 36:91. 1963, figs. 45, 46. Wirth has declined to study the Galápagos material because of pressing teaching obligations.

San Salvador: on *Bursera*, *Pike 56483*.

***Graphis caesiella** Vain.

Santa Cruz: *Lich. Exs. COLO 480*, Santa Fé. A very common species on *Croton* but also on *Bursera* and other trees.

***Graphis desquamescens** Fée.

Santa Cruz: on *Bursera*, Academy Bay, *54823*.

***Graphis striatula** (Ach.) Spreng.

Santa Cruz: On *Castela galapageia*, *Lich. Exs. COLO 142*.

***Graphis subamylacea** A. Zahlbr.

Santa Fé: on *Opuntia echios*, *54830*; Santa Cruz: on *Bursera*, Academy Bay, *54822*.

***Gyalectidium filicinum** Müll.-Arg.

Floreana: 63344; Santa Cruz: 40211 (with *Tapellaria nana*), *40216*, *40217*, *40432*, *40433* (in packet of *Aspidophyllum fugiens*), *40434*, *63497*. !Vezda. On leaves of *Miconia*, *Coffea*, and ferns, in the moist zone.

***Haematomma puniceum** (Sm. *ex* Ach.) Mass. (*Lecanora punicea* of previous reports).

Rábida, Floreana, Santa Cruz, San Salvador. Common on *Bursera* and other trees in the cactus forest zone. An unmistakeable lichen with white thallus and bright red apothecia.

***Herpothallon sanguineum** (Sw.) Tobler. *Chiodecton sanguineum* (Sw.) Vain.

Fernandina, Pinta, Rábida, San Salvador, Santa Cruz. A unique lichen common on trees of the moist zone, forming great gray and blood-red splotches.

***Heterodermia albicans** (Pers.) Swinscow & Krog, Lichenologist 8:113. 1976. *Physcia albicans* (Pers.) J. W. Thomson.

San Salvador, Santa Cruz, Wolf. Common on living fences of *Jatropha curcas*, moist zone. Thalli sterile, white, radiate, flat or concave, the older parts with marginal soralia; cortex K+ yellow or yellowish (atranorine & norstictic).

***Heterodermia antillarum** (Vain.) Swinscow & Krog, Lichenologist

8:114. 1976. *Anaptychia tropica* Kurok. var. *antillarum* (Vain.) Kurok.

Floreana, Fernandina, Rábida, Santa Cruz. Frequent on trees, dead wood in the cactus forest, and occasionally on shore rocks. Thallus ivory-textured, white with gray tones especially on the essentially marginal isidia, white beneath. Never associated with mosses but directly attached to the substrate.

Heterodermia comosa (Eschw.) Follm. & Redon, Willdenowia 6:446. 1972. *Anaptychia comosa* (Eschw.) Mass., *A. podocarpa* of reports).

San Salvador: *Taylor 916* (MO), *Pike 56164*; Santa Cruz: *40741, 41131, 44036*. Never common, occurring scattered on small twigs in the *Scalesia* forest area. Forming isolated rosettes with ascending short laciniae and long white marginal cilia. When sterile some lobes are cucullate and sorediate beneath; the apothecia, when present, are pruinose and ciliate.

***Heterodermia corallophora** (Tayl.) Skorepa, The Bryologist 75: 490. 1972. *Anaptychia corallophora* (Tayl.) Vainio.

San Cristóbal, *Lanier 63755*; Santa Cruz: on *Psidium*, *40708*, *41145*, *Sipman 63493*. Characterized by a soft foliose greenish thallus with numerous laminal isidia. All material is sterile.

***Heterodermia lepidota** Swinscow & Krog, Lichenologist 8:122-124. plate 2. 1976.

Isabela: Volcán Cerro Azul, S slope, above Iguana Cove, 250 m.s.m., on slanting trunk of *Pisonia*, *Sipman 63504*. Thallus characterized by entire or dissected laminal squamules and/or soredia or isidia (ours also has isidia). In contrast to *H. antillarum*, the thallus is broader and forms large round plaques instead of linear radiant lobes and it lacks the firm ivory-white cortex.

***Heterodermia leucomela** (L.) Poelt *sens. lat.* See Swinscow & Krog, Lichenologist 8:134-129. 1976. (*Physcia leucomela* of reports).

Rábida, Floreana, Isabela: *Lich. Exs. COLO 508* (as *Anaptychia stellata*), *509* (f. *verrucifera*), Pinta, San Salvador, Santa Cruz. Locally abundant on trees and shrubs in the moist zone. Long narrow ribbons, white above, white beneath, with long black cilia; thallus straight or circinate at the apex; sometimes isidiate. Until detailed microchemical study is made of these collections it seems best to lump them under *H. leucomela*. Numerous segregates have been proposed. *Lich. Exs. 504*, distributed as *Anaptychia circinalis* (Zahlbr.) W. A. Weber, is one such, having slender, terete branches and circinate branch tips. This grows in sites with typical flat-laciniate *H. leucomela* without intergradation.

Heterodermia lutescens (Kurokawa) Follmann, Philippia 2:73. 1974.

Isabela: *Sipman 63549*; Pinzón: *Sipman 63581*; Santa Cruz: *63487*. The thallus characteristically has a lemon-yellow pigment on the lower surface, and is sorediate near the lobe tips.

Hypotrachyna costaricensis (Nyl.) Hale. *Parmelia costaricensis* Nyl.

Santa Cruz: fern-sedge zone, summit area between Cerro Crocker and El Puntudo, on *Scalesia pedunculata*, *63053*. Thallus gray, smooth and shiny, with long cylindric isidia; rhizinae branched, underside black. No chemical reactions.

Hypotrachyna microblasta (Vain.) Hale. *Parmelia microblasta* Vain.

San Salvador: *Pike 56194*; Santa Cruz: El Puntudo, summit grassland, *55396*. Yellow, isidiate, rhizinae dichotomous, no pseudocyphellae, maculae or fissures; med. white, Pd+ yellow, K+ yellowish, underside black.

Lecanora caesiorubella Ach. ssp. **glaucomodes** (Nyl.) Imshaug & Brodo, Nova Hedwigia 12:15.1966.

Santa Cruz: Common on *Piscidia*, cactus forest. Thallus white; apothecia pruinose, slightly contorted; margin K+ yellow to red (norstictic), Pd+ orange, (protocetraric), C-.

Lecanora leprosa Fée. See Brodo (1984).

Floreana, Rábida, Santa Cruz, Wolf. A very common corticolous species on a variety of trees in the cactus forest; also on mangroves. Superficially similar to *Lecidea granifera* but with thinner apothecial margins, and with algae in the margin.

Lecanora pseudopinguis W. A. Weber, Mycotaxon 13:102-103. 1981.

Endemic. Champion, Floreana, Isabela, Rábida, Plazas, San Salvador, Santa Cruz: *Lich. Exs. COLO 500* (Type). One of the dominant lichens of the coastal rocks and seaward-facing barrancos (one collection from 400 m.s.m.). Thallus and apothecia dull yellow, C+ orange. Thalli at the type locality were so badly damaged from fresh-water scouring during the 1982 El Niño as to be unrecognizable.

Lecanora sulfurescens Fée

Darwin, Plazas, San Salvador, Santa Cruz, Wolf. Common on lava rocks near the coast but generally well back from the high tide mark. Thallus crustose, white, with small, flat areolae; apothecia from reddish brown to pale yellowish-brown, usually immersed or nearly so, with a narrow rim.

***Lecidea chilena** Zahlbr. *L. aeruginosa* Nyl. For description, see Zahlbr. in Skottsberg, Acta Horti Goteb. 2:9. 1926.
Floreana: on lava, rocky point just south of Black Beach, *63013*; Santa Cruz: on lava, Academy Bay, *40834*. Disjunctive from Chile. The green-pruinose apothecia are distinctive.

***Lecidea** *cf.* **granifera** (Ach.) Vain.
Santa Cruz: *40082*, *40197*, *40337*, *40423*, *40475*, *40616*; San Salvador: *40089*, *41028*. A white crust on various trees in the cactus forest. The apothecia superficially resemble those of *Lecanora leprosa*, but algae are absent from the thicker margin and below the hypothecium. Our collections are not warty as they usually are in Florida collections, and may represent a segregate. It is highly unlikely that this taxon will remain in *Lecidea*.

***Lecidea oreinoides** (Koerb.) Weber & Hertel *in* Hertel, Herzogia 2:493, 1973.
Santa Cruz: *40039*, *40067*, *40860*, *40862*, *40867*, *40871*. Frequent on boulders on shore and in the cactus forest. A ubiquitous lichen of the subtropics of both hemispheres. It has received very many names, first under Aspicilia, which it superficially resembles. Thallus white, cracky-areolate, with black prothalline lines visible between the areoles; apothecia round, totally immersed and occasionally running together.

***Leprocaulon tenellum** (Tuck.) Nyl.
Fernandina, Floreana, Isabela, San Cristóbal, San Salvador, Santa Cruz: *Lich. Exs. COLO 496* (as *L. microscopicum*). Common on exposed crater rims often bathed in fog. Also present on the mainland coast of Peru and Chile.

***Leptogium cyanescens** (Ach.) Koerb.
Santa Cruz: *Lich. Exs. COLO 506*. On living fences in the cultivated zone, and on the ground in summit heath. Thallus slate gray, naked below, scarcely wrinkled, with cylindric to flattened isidia on upper surface and margins.

***Leptogium isidiosellum** (Riddle) Sierk, Bryologist 67:282-283. 1964.
Santa Cruz: on lava boulders, base of first barranco along old trail to Bella Vista, lower edge of Transition zone, *40274*. Thallus brown to blue-gray, densely isidiate, with "pulled"

wrinkles beneath. The habitat, *fide* Sierk, is corticolous.

Leptogium marginellum (Sw.) S. Gray
Floreana, Isabela, San Salvador, Santa Cruz. Common on trees in the moist zone. Characterized by marginal, light-colored apothecia, surrounded by cylindrical clavate or lobulate isidia; both sides of thallus distinctly sharp-wrinkled.

***Leptogium millegranum** Sierk, The Bryologist 67:290. 1964.
Fernandina, San Salvador, Santa Cruz. Frequent on smooth-barked trees in the cactus forest and lower Transition zone. Thallus lead gray to greenish black, with alternating exceedingly thin, stretched areas and elongate high ridges covered with small dark isidia.

***Leptogium punctulatum** Nyl.
Santa Cruz: *Scalesia pedunculata* forest, north slope of Mount Crocker, 650 m.s.m., *61462*, *Lich. Exs. COLO 505*. !P. M. Joergensen. Forming densely tufted ascending or erect thalli on horizontal branches of *Scalesia* on forest margin. Thallus steel-gray, foveolate, broad-lobed, no tomentum or isidia; apothecia common, sessile, amphithecium pale tan.

***Lobaria dissecta** (Sw.) Raüsch.
Pinzon: mixed *Scalesia* forest of trees 4 meters tall, only one thallus seen, on *Scalesia* branch, *Sipman L-63580*. Thallus shining ivory-white above, tan, naked below; lobes with rounded sinuses.

***Lopadium foliicola** (Fée) R. Sant.
San Cristobal: on *Citrus* leaves below Tres Palos, *Lanier L-63763*. !Vezda.

***Lopadium fuscum** Müll.-Arg.
San Cristóbal: on *Persea americana* leaves at Tres Palos, *Lanier 63700*; on leaves of *Coffea*, Horneman farm, *40431*. !Vezda.

***Lopadium puiggarii** (Müll.-Arg.) A. Zahlbr.
Santa Cruz: *40216 p.p.*, *40264*, *40265*, *40266*, *40435*, *63331*. !Vezda. On leaves of various plants (*Miconia robinsoniana*, *Pteridium aquilinum*) in the moist zone and summit heath.

***Melanotheca cruenta** (Mont.) Müll.-Arg.
San Salvador: on twigs, *Pike 54809*. Thallus thin, smooth, stained a dull red-orange, darker where the clusters of raised perithecia occur.

***Myriotrema compunctum** (Ach.) Hale, Mycotaxon 11:133. 1980.
Leptotrema compunctum (Ach.) Müll.-Arg. See Redinger (1936).

San Salvador: *Pike 56165*; Santa Cruz: *40347, 40357, Lich. Exs. COLO 643*, !Hale. Forming large gray unbroken sheetlike crusts on *Bursera* in the cactus forest; apothecia immersed, minute, the disk dilated, pruinose.

Myriotrema olivaceum Fée

San Salvador: on *Xanthoxylum*, 530 m.s.m., *Pike 55414*. !Hale. Thallus smooth, conforming to the bark, pale tan, apothecia in the depressions, in groups, not raised, the openings minute (0.1 mm).

***Myriotrema wightii** (T. Tayl.) Hale, Mycotaxon *op. cit.* p. 135.
Leptotrema wightii (Tayl.) Müll.-Arg.

Isabela: Cerro Azul, *Sipman 63506*; Santa Cruz: *40539*. On *Pisonia* and *Bursera*, often on dead wood. Thallus gray, thick, continuous; apothecia immersed, punctiform, not raised, visible as black-brown dots.

***Niebla** *sp. nov. ined. Ramalina ceruchoides* H. Magn. *ined.*

Pinzón: 375 m. on vertical face of big boulder, *Sipman 63573*. Extremely fragile. Thallus terete and slender, yellowish, the branch tips with exposed medulla or incipient soredia. Although this is undescribed, it is important for the record, since this material matches *Santesson 1645*, from Chile: Prov. Atacama: Copiapo, on rocks in the desert NW of the town, 9.vii.1940. This is not the same plant as *Niebla ceruchoides* Rundel & Bowler, *ined.*, from California, which is not at all fragile, esorediate, and green.

***Normandina pulchella** (Borrer) Nyl.

Santa Cruz: (in packet with *Byssoloma subdiscordans*) *40250*; San Salvador: *56158*. On leaves of *Eugenia jambos* and *Xanthoxylum*, moist zone.

Ochrolechia pallescens (L.) Mass.

Floreana, Pinzón, San Cristóbal, San Salvador, Santa Cruz, Santa Fé. Warty gray crust with large thick-margined apothecia; disk pinkish.

***Pannaria pannosa** (Sw.) Del. *Parmeliella pannosa* (Sw.) Müll.-Arg.

Isabela: Cerro Azul, south slope above Iguana Cove, 250 m.s.m., on a slanting *Pisonia* trunk, *Sipman 63501*. Thallus sterile, densely isidiate except for the very margin, black pannose-rhizinate below.

***Parmentaria astroidea** Fée

Santa Cruz: on *Ochroma* (balsa) trees in plantation at Bella Vista, *54837*. Resembling *Pyrenula nitida* but perithecia grouped and with a paler central wart, in section showing this to be a focus of canals running from the various perithecia.

***Parmotrema conformatum** (Vain.) Hale. *Parmelia conformata* Vain.

Floreana: on *Bursera*, trail from Black Beach to highlands, *62917*. !Hale. Thallus yellow, black beneath, with incipient soredia on ridges and margins.

***Parmotrema crinitum** (Ach.) Choisy. *Parmelia crinita* Ach.

San Salvador: *56192*; Santa Cruz: Academy Bay, on *Bursera*, *40622a*, *40625a* (with *P. endosulphurea*). Thallus ciliate, isidiate, black beneath margin brown, bare; med. K+ yellow, C-.

***Parmotrema cristiferum** (Tayl.) Hale. *Parmelia cristifera* Tayl. (*Parmelia perlata* and *latissima* of reports).

Fernandina, Floreana, Santa Cruz. Very common on smooth barked trees, cactus forest through transition and moist zone. Thallus with sorediate margins, no marginal cilia, cortex K+ yellow, medulla K+ red, Pd+ orange-red, C-, K-.

***Parmotrema dilatatum** (Vain.) Hale. *Parmelia dilatata* Vain.

Santa Cruz: on rocks just above high tide mark, *40057*, *40820*, *40873* !Hale. Thallus gray-white, sorediate on upper side at lobe tips, no cilia, cortex K+ yellow, medulla white, K-, Pd+ yellow-orange, C-.

***Parmotrema dominicanum** (Vain.) Hale. *Parmelia dominicana* Vain.

Floreana, *62912*, *62913*; Santa Cruz: *40122*, *41186*, *40890*, *Lich. Exs. COLO 136*. !Hale. On *Laguncularia* and smooth-barked trees of the cactus forest at low altitudes. Soralia greenish (usnic acid), marginal on upturned lobes, cortex K+ yelow, Pd+ orange.

***Parmotrema eborinum** (Hale) Hale. *Parmelia eborina* Hale.

Pinzón: caldera rim, 300 m.s.m., *40237*, *40505*. !Hale. Thallus lacking soredia or isidia, ashy-white, often monophyllous, fragile when dry, K+ yellowish, KC+ red, Pd+ orange.

***Parmotrema endosulphureum** (Hillm.) Hale. *Parmelia endosulphurea* Hillm.

Pinzón: *40236*, *Stewart 3367* (FH, as *P. latissima*); San Salvador: *Stewart 1004* (FH, as *P. latissima*). Santa Cruz: *40120*, *40239*, *40282 p.p.*, *40624*, *40625*. On *Bursera*, *Pisonia*, and other smooth-barked trees in the cactus forest. Thallus eciliate, isidiate, medulla pale yellow.

***Parmotrema hypotropum** (Nyl.) Hale. *Parmelia hypotropa* Nyl.
Santa Fé: *Orr 40415*. !Hale. Thallus ciliate, cortex maculate, med. K+ red (atranorine and norstictic).

***Parmotrema leucosemothetum** (Hue) Hale. *Parmelia leucosemotheta* Hue
Pinzón: *Cavagnaro 40151, 40159, 40494*. On *Croton* bushes, summit of the island. Thallus marginally sorediate, ciliate, maculate, with pale blotches underside at margin, Med. K+ yellow-red (salacinic and atranorine), P+ pale orange-red, C-, KC-, cortex K+ yellow.

Parmotrema peralbidum (Hale) Hale. *Parmelia peralbida* Hale
Floreana: *62905*; Santa Cruz: *40413, 40545, 63065*. On *Bursera* in the cactus forest. A rather small *Parmotrema*, tightly adnate; thallus white, soft and fragile, with many minute isidia, becoming + sorediate; cortex K+ yellow, med. K-, C-, KC+ rose (fleeting), Pd+ orange (atranorine and protocetraric).

***Parmotrema praesorediosum** (Nyl.) Hale. *Parmelia praesorediosa* Nyl.
Pinzón: *40499, 44017*; Santa Cruz: *40446, 40542, 40621*. !Hale. On smooth-barked trees in the cactus forest, only rarely on rock. Thallus white, eciliate, soralia marginal, forming elongate, sinuous crescentic areas; noticeably thinner in comparison with *P. cristifera*.

***Parmotrema reticulatum** (Tayl.) Choisy. *Parmelia reticulata* Tayl.
Pinzón: *50517*; San Salvador: *Pike 55194*; Santa Cruz: *40511, 40540, 55398*. On trees (*Xanthoxylum* and *Croton*) and rocks in the transition zone and summit grassland. Thallus with fine reticulate cracks, ciliate, with laminal and marginal soredia; med. K+ yellow-red (atranorine).

Parmotrema tinctorum (Nyl.) Hale. *Parmelia tinctorum* Nyl.
Isabela, Pinzón, San Salvador, Santa Cruz, *Lich. Exs. COLO 114*. Wolf. Abundant on smooth-barked trees in the cactus forest, occasionally on Jasminocereus and rocks. A large *Parmotrema* with pearl gray thallus with broad rounded lobes, simple or branched laminal isidia; medulla C+ red.

***Parmotrema ultralucens** (Krog) Hale. *Parmelia subcrinita* Nyl.
Floreana: 62915, *Taylor 868* (MICH); Pinzón: *40491, Stewart*

349 p.p. (FH, as *P. latissima*); Santa Cruz: *40011, 40292, 63059.* !Hale. Wide ranging from cactus forest to summit heath, on trees and rocks. Thallus not maculate, ciliate, isidiate, isidia simple; lower side black with marginal naked area; medulla white, C-, K+ red (salazinic).

***Parmotrema xanthinum** (Müll.-Arg.) Hale. *Parmelia xanthina* (Müll.-Arg.) Vain.

Pinzón: caldera rim, 300 m.s.m., *Cavagnaro 40757.* Substrate not indicated. Thallus yellow (usnic), cortex K+ yellow, ciliate, med. white, underside naked at margin, medulla nonreactive.

***Peltigera dolichorhiza** (Nyl.) Nyl.

Isabela: Cerro Azul, south slope above Iguana Cove, 800 m.s.m., on steep mossy bank among ferns, *v. d. Werff 64414, 64415.*

***Peltigera erumpens** (Tayl.) Elenk.

Isabela: Cerro Azul, 750 m.s.m., *Sipman L-52*; Santa Cruz: on bare soil, summit heath, *40302, 41144.* Gray-brown squamules with erumpent patches of gray soredia in the center. Vitikainen, in Poelt & Vezda (1981) treating *P. spuria*, evidently does not include a esorediate form (*P. erumpens* [Tayl.] Elenk., *P. hazslinszkyi* Gyelnik) in his species concept. *P. didactyla* (With.) Laundon is the correct name for the fertile form of *P. spuria.* I am not convinced that it is related to the sorediate plant.

***Peltula euploca** (Ach.) Wetmore

Champion: *62786*; Darwin: *Dawson 40900, 40901*; Santa Cruz: *40071*; Wolf: *Cavagnaro 40917.* A very inconspicuous lichen of lava boulders near the shore. Thallus consisting of a single thick squamule the color of the rock; margin gray, roughened.

Pertusaria albinea Tuck., Proc. Amer. Acad. 12:177. 1877.

Endemic. Type from "Galápagos Islands", *Rev. T. Hill (Hassler Exped.).* Santa Cruz: *40346* appears to be a match for the type. On *Bursera.* A smooth white species with low hemispherical warts with a small dark ostiole; no soredia or isidia.

Pertusaria bispora (Farlow) Linder, Proc. Calif. Acad. Sci. 21: 213-214. 1934.

Genovesa, San Salvador, Santa Cruz. Thallus thin, smooth, yellow, the ascocarps forming low mounds. Yellow *Pertusaria* resembling this are common around the Pacific Basin from California to Australia. It is unlikely that this name will be the oldest one available. *P. pustulata* (Ach.) Duby seems to be a likely possibility.

***Phaeographis dendritica** (Ach.) Müll.-Arg.

Fernandina, Floreana, San Cristóbal, Santa Cruz, San Salvador. Common on *Bursera* and other smooth-barked trees in the cactus forest. A distinctive species. Thallus white, extensive; apothecia lirelliform, radiating, gray-pruinose, tapered at the ends.

***Phyllopsora corallina** (Eschw.) Müll.-Arg.

Floreana: on *Psidium guajava*, *62909*; Santa Cruz: common on living fences of *Jatropha curcas*, Horneman Farm, *40262*. Thallus of narrow green isidia standing on a mat of loosely interwoven brown hyphae prominent around the thallus margin; apothecia immature in ours, brown, biatorine.

***Physcia callosa** Nyl.

Santa Cruz: *40013*, *40343*, *40198*, *40449*. Rare or infrequent on lava blocks of barranco slope just north of Darwin Station, vicinity of seismic station. Thallus white, finely dissected and loosely attached, with coarse round soredia arising from the underside of the lobe edges.

***Phaeophyscia hispidula** (Ach.) Esslinger

Isabela: Cerro Azul, south slope above Iguana Cove, 250 m.s.m., on *Pisonia*, *Sipman 63502*, *63503*. !Esslinger. Thallus gray, with round greenish soralia and a dense mat of black stiff rhizinae visible at the margins.

Physcia insularis A. Zahlbr., Ann. Mycol. 29:86. 1931.

Endemic. Floreana: Post Office Bay, *Herre* (Type in Viena); Santa Cruz: *30434*, *40198*, *40389*, *40449*. Zahlbruckner described this species as being sorediate and the medulla K-. The cited specimens agree with this. Thomson (1963 p. 44) wrote: "Although *P. insularis* is described as being sorediate, isotypes of the original Galápagos Island material (*Krypt. Vind. 3170*) have been examined in the U. S. National Herbarium and the herbarium of the University of Colorado. These are not sorediate but have the heavy coat of pruina of [*P. biziana*]." But the exsiccati did not claim to be the type collection, only "*ex loco classico*"! Thomson never saw the type, which Zahlbruckner did not identify by number. Both *P. insularis* and an esorediate species with pruinose apothecia and medulla K+ yellow (here identified as *P. mexicana* B. de Lesd.) are abundant on *Bursera* at Post Office Bay and the exsiccati may in fact consist of a mixture with various packets having one or the other species.

***Physcia mexicana** B. de Lesd.
Floreana: Post-office Bay, *54827*; San Salvador: James Bay, *Dawson 41021*. Thallus white, esorediate, the lobes narrow and convex; apothecia pruinose; medulla K+ yellow.

***Physcia lacinulata** Müll.-Arg.
Fernandina: west side of island, 320 m.s.m., on *Bursera*, *Cavagnaro 40231*. !Esslinger. This is the first collection from south of Costa Rica and the first in fruiting condition since the type. Thallus tan-ash-brown, upper side K-, epruinose, with numerous crowded-squamulose isidia or microlobules; marginal lobes short, flabellate.

Physcia sorediosa (Vain.) Lynge
Fernandina: *40471*; Floreana: *Taylor 858* (specimen not found at MO), reported by Dodge (1936); Santa Cruz: *40240-40242*. A large *Physcia*, white or yellowish, with closely contiguous plane marginal lobes; soredia coarse, in globular laminal soralia, becoming so numerous as to obscure the thallus surface; apothecia usually present, with prominent smooth rim; cortex and medulla K+ yellow; underside black.

***Physma byrsinum** (Ach.) Müll.-Arg.
Isabela: Cerro Azul, on *Scalesia* trunk, south slope above Iguana Cove, 350 m.s.m., *Sipman 63535*. Thallus thick, swelling when wet, ashy-gray, much wrinkled and foveolate when dry; apothecia numerous, large, with reddish-brown disk and wrinkled gray margin.

***Pseudocyphellaria argyracea** (Del.) Vain.
Pinzón: 450 m.s.m., on shrubs on exposed rock ridge with ferns and scattered shrubs, *Sipman 63582*. Thallus brown with white dorsal pseudocyphellae developing clusters of brown isidia; underside brown-tomentose with large white pseudocyphellae.

Pseudocyphellaria aurata (Ach.) Vain.
Fernandina, Floreana, Isabela, Pinzón, San Cristóbal, Santa Cruz, San Salvador. Infrequent on trees and shrubs in the moist zone, not as common as its collections indicate, since it is taken wherever encountered, because of its striking appearance. Thallus gray with yellow underside and yellow pseudocyphellae; soredia marginal, yellow. Some specimens must differ chemically, for on drying some soon turn dull brick red while others remain gray. This does not seem to depend in the manner of desiccation.

***Pseudocyphellaria crocata** (L.) Vain.
San Salvador: *Pike 56162*; Santa Cruz: Table Mt., *40514*, *41184*. Less frequent than the last. Thallus green-brown, underside tan, tomentose, with yellow pseudocyphellae; upper surface with marginal and laminal yellow soredia.

***Pseudocyphellaria mougeotiana** Vain. var. **aurigera** (Del.) Vain. *P. xantholoma* (Del.) Dodge.
Floreana: *Itow 40719, 40758*; San Salvador: *Pike 56182*; Santa Cruz: Table Mountain, 40487. Infrequent, on trees and shrubs in the moist zone. Thallus shiny brown with elongate marginal and laminal gray soralia, eroding to expose a yellow medulla, dark tomentose beneath, naked and pale brown near the margins.

***Pseudoparmelia caroliniana** (Nyl.) Hale. *Parmelia caroliniana* Nyl.
Isabela: *Sipman 63538, 63547*; Santa Cruz: *40384, 44028, 44031*; San Salvador: *Pike 55210, 56488*. On various trees in the moist zone. Thallus yellowish-green, isidiate or pustulate, the isidia narrow and elongate, tending to be in clusters and often branched; cortex surface minutely ridged or wrinkled.

***Pseudoparmelia leucoxantha** (Müll.-Arg.) Hale
Floreana: trail from Black Beach to highlands, *62892*. !Hale. On rocks; thallus yellow, laminally and marginally sorediate, black beneath; sterile.

***Psoroglaena cubensis** Müll.-Arg., Flora 74:381. 1891.
Reported by Dodge (1936), from Hood: on rock, islet, Gardner Bay, *Taylor 872*. The specimen (FH) is a species of *Peltula*. However, I have collected the real *Psoroglaena cubensis* and report it here. Santa Cruz: on old fern rhizomes, base of the first barranco behind the Darwin Station, in shaded talus, *40298*. Sterile. A minutely foliose olive green thallus, irregularly dichotomous-pinnately divided. The type collection was also collected on fern rhizomes, possibly an obligate substrate.

Pyrenula cerina Eschw. *P. aurantiaca* Fée
Genovesa, Isabela, Marchena, Rábida, Santa Cruz: *Lich. Exs. COLO 146*, San Salvador. Common on smooth barked trees and branches, aerial roots of mangroves, etc., mangrove zone, coastal scrub and lower cactus forest. A bright orange thin crust with minute perithecia in surface depressions.

***Pyrgillus javanicus** Nyl.

Santa Cruz: on decorticate, termite-worked wood of dead leaning *Bursera* tree, cactus forest just north of Darwin Station, 30 m.s.m.

Pyxine berteriana (Fée) Imshaug
Santa Cruz: *40355, 63281.* On *Bursera* in the cactus forest. Thallus with radiating plane or concave lobes, smooth, not pruinose, flabellate-lobed, esorediate, UV+ yellow; medulla pale yellowish; apothecia black, sessile, hypothecial stipe absent. Compares well with Kalb: *Lich. Neotropici 194.*

***Pyxine caesiopruinosa** (Tuck. *in* Nyl.) Imshaug
Santa Cruz: on talus of first barranco near seismic station behind Darwin Station, *40876.* Thallus dark gray, paler near the margins, with small capitate laminal soralia; medulla where broken showing through as pale salmon color; UV+ yellow. Compares exactly with *Imshaug 24790*, from Cuba.

***Pyxine cocoes** (Sw.) Nyl.
Plazas: *40600*; Santa Fé: *40428*; San Salvador: *Pike 55407.* Thallus white, often with thick pruina; soredia copious on lamina and margin; thallus not reticulate, medulla white; hypothecial stipe K+ red; UV+ yellow.

***Pyxine connectens** (Vain.) Malme
Floreana: *62907* (matched with the holotype), Isabela, Pinta, San Salvador, Santa Cruz, Wolf. Common on *Bursera*, *Acacia*, and occasionally *Opuntia.* Thallus thick, plane, marginally so rediate, often the older parts cracked, the younger lobes with a crustlike pruina, cortex K-, UV+ yellow.

***Pyxine eschweileri** (Tuck.) Vain.
Floreana, Pinzón, Santa Cruz. Equally common on trees and rocks in the coastal and cactus forest zone. Similar in appearance to *P. connectens* but thallus UV-; medulla somewhat yellowish.

***Pyxine pringlei** Imshaug, Trans. Amer. Microscopic Soc. 76:263. 1957.
Floreana, Santa Cruz: *Lich. Exs. COLO 111*; Wolf. Common on lava rocks in the cactus forest. Thallus pale yellow with black plane apothecia; stipe reddish, K+ purple. UV+ yellow.

***Ramalina anceps** Nyl.
Rábida: *Stewart 421* (as *Alectoria sarmentosa*). !Rundel, 1975. Similar to *R. usnea* but with salazinic and norstictic acids (*R. usnea* lacks norstictic acid).

Ramalina complanata (Sw.) Ach.
Santa Fé: *Orr 40416*; Wolf: *Schuster 40230*. !Rundel. On coastal shrubs. Thallus rigid, flattened, foveate and longitudinally ridged, containing usnic and divaricatic acids.

***Ramalina denticulata** (Eschw.) Nyl.
Española, Genovesa, Isabela, Plazas, San Cristóbal, Santa Cruz, *Lich. Exs. COLO 147* (as *R. complanata*), Santa Fé, San Salvador, Tortuga, Wolf. All !Rundel. Similar to *R. complanata* and usually so reported, but with salazinic acid.

***Ramalina furcellata** (Mont.) Zahlbr.
Floreana, Pinzón, Rábida, San Salvador, Santa Cruz. On coastal shrubs. Thallus with basal parts flattened, branches terete, erect or somewhat pendulous, with soredia arising from pseudocyphellae; medulla Pd+ yellow; very fragile when dry.

***Ramalina linearis** (Sw.) Ach.
Floreana, Isabela, Santa Cruz, Santa Fé. Thallus narrow, thin, deeply and often connivent-canaliculate, with marginal apothecia; soredia and isidia lacking; med. K+red, Pd+ yellow.

***Ramalina peruviana** Ach.
Floreana: *40777*; Santa Cruz: *40286, 44035, 40697*; San Salvador: *Pike 55419*. All !Rundel. On coastal rocks, and also on shrubs in the transition and moist zones. Thallus almost terete but somewhat angular and striate, cracked on the edges and with small soralia; sekikaic and ramalinolic acids. Several specimens, thought to be this species, were held aside by Rundel because they contain salazinic acid.

***Ramalina soredianthа** Nyl.
Santa Cruz: *Lich. Exs. COLO 137*. Common on *Jatropha curcas* living fences, Bella Vista. Thalli forming small balls, laciniae slender, canaliculate, with ball-like soralia on the branch tips; medulla K+ red, Pd+ yellow.

Ramalina usnea (L.) Howe
Española, Floreana, Pinzón, Rábida, San Cristóbal, Santa Cruz: *Lich. Exs. COLO 115*, Santa Fé, San Salvador. An extremely abundant species in the transition and moist zones, festooning trees wherever fog persists. Probably some of the material will prove to belong to *R. anceps*; the lines separating these taxa are not clear to me.

Roccella babingtonii Mont. *R. intricata*, *R. peruensis*, of previous reports.

Baltra, Bartolomé, Daphne Major, Española, Floreana, Genovesa, Isabela, Pinta, Pinzón, Rábida, San Cristóbal, Santa Cruz: *Lich. Exs. COLO 109*, Santa Fé, Wolf. Extremely abundant on often moribund trees (*Bursera*, *Acacia*) and coastal shrubs. One of the commercial sources of orchil, formerly collected on the islands for commercial exploitation of the dyestuff by factories on the mainland. Thallus gray, flattened, with broadly linear branches, sorediate; cortex C+ red (lecanoric acid).

***Roccella galapagoensis** Follmann, Nova Hedwigia 15:337-340. 1968. *R. portentosa*, incorrectly, of reports.

Baltra, Bartolomé, Darwin, Española, Floreana, Gardner, Isabela, Pinzón, Santa Fé, San Salvador, Santa Cruz: *Lich. Exs. COLO 112*, Type; Wolf. Locally abundant on coastal rocks. Thallus terete, to 5 mm thick, forming long ropy strands ascending at the ends; apothecia immersed, round, black. Chemically vari able, containing erythrin, galapagin, portentol, protocetraric acid, roccellic acid.

***Roccellina badia** Tehlér, Opera Bot. 70:67. 1983.

Floreana: *62896*; San Salvador: *56478*: Santa Cruz: *40824*, *62854*. On massive lava blocks usually vertically exposed. Thallus thin, minutely areolate, creamy white with a purplish cast, occasional point soredia scattered; apothecia tan, with concolorous rim. Cortex C+ red. Known only from Galápagos and adjacent coastal Peru.

Schistophoron tenue Stirton

Santa Cruz: *Herre 41158*, *Lich. Exs. COLO 495*; Isabela, *Sipman 63512*. On smooth-barked trees (*Pisonia*), once collected (Isabela) on decaying plant bases. Collected at Academy Bay in 1929 by Herre, I did not rediscover this species until 1976, when I found an entire tree trunk covered with it. For many years known only from Galápagos and west Africa, it recently has been discovered on the Ecuadorean mainland. Thallus smooth, white; fruiting structures dome-shaped, sometimes curved and slightly elongate, with a black, simple or sometimes forked median line.

***Sphinctrina podocarpa** Müll.-Arg.

San Salvador: on **Pertusaria**, in *Psidium-Bursera* forest on pahoehoehoe lava flow near salt lake on James Bay, 170 m.s.m., *Pike 56178*. Podetia nine-pin-shaped, red-brown with bluish base, 0.5 mm high.

***Spilonema revertens** Nyl.

Santa Cruz: on lava blocks along old trail from Puerta Ayora to Bella Vista, *63304*. Forming inconspicuous black balls a few mm diam, in and around crevices of the rock. Thallus minutely fruticulose, the base distinctly bluish where separated from the substrate.

***Sporopodium leprieurii** Mont.

Santa Cruz: on leaves of *Miconia robinsoniana*, summit area, *40213*. !Santesson.

***Stereocaulon azulense** Yoshimura & W. A. Weber, *sp. nov*. See Appendix III.

***Stereocaulon microcarpum** Müll.-Arg.

San Cristobal: El Junco, *Lanier 63748, 63761*. On lava rocks.

**Stereocaulon weberi* Lamb, J. Hattori Bot. Lab. 43:258. 1977.

Isabela: *75985*, *Sipman 63528*; San Cristóbal: El Junco (mixed with *S. microcarpum*), *Lanier 63748 p.p.*, *63762 p.p.*; Santa Cruz: *Lich. Exs. COLO 494* (Type, distributed as *S. microcarpum*), 63061, 63038. On lava, summit areas of the higher islands. Thallus erect, little-branched, with granulose-serediiform phyllocladia.

***Sticta filix** (Sw.) Nyl.

Santa Cruz: *40509, 40512, 44027, 55388, 55402*; San Salvador: *Pike 55422*. On *Scalesia* trees in the moist zone. Thallus monophyllous, fern-like, erect, green when wet, brown beneath with prominent "veins", finely laciniate with a thickened basal holdfast, the rhizinae very short.

***Sticta fuliginosa** (Dicks.) Ach.

San Salvador: in dense stand of *Xanthoxylum* and *Psychotria* between James Bay and summit, 780 m.s.m., *Pike 55421*. Thallus monophyllous, gray with broad rounded lobes, above with very fine black cylindrical isidia in clumps; underside pale.

***Sticta sylvatica** (Huds.) Ach.

Santa Cruz: *40430*; San Salvador, *Pike 55423*. On *Miconia* and other shrubs. Thallus gray, with rounded lobes, surface with scattered lead-gray isidia, underside pale, with pale rhizinae. Our specimens very small and fragmentary.

Sticta weigelii (Isert *ex* Ach.) Vain.

Isabela, San Salvador, Santa Cruz. Omnipresent species on trees and shrubs in the moist zone. Thallus brown to purplish-black. margins (and often lamina) isidiate, smooth (or in *forma peruviana* [Del.] Vain.) depressed-reticulate.

***Strigula nitidula** Mont.
Santa Cruz: on leaves of *Eugenia jambos*, along trail to Horneman place just above Bella Vista, *64131 p.p.* (with *Byssoloma subdiscordans*). !Vezda.

***Strigula subtilissima** (Fée) Müll.-Arg.
Santa Cruz: on leaves of *Eugenia jambos*, along trail to Horneman place just above Bella Vista, *64131 p.p.* (with *Byssoloma subdiscordans*). !Vezda.

***Tapellaria epiphylla** (Müll.-Arg.) R. Sant.
San Cristóbal: on *Citrus* leaves below Tres Palos, *Lanier 63764*. !Vezda; Santa Cruz: on leaves of *Eugenia jambos*, along trail to Horneman place above Bella Vista, *42047* (with *Byssoloma subdiscordans*). !Vezda.

***Tapellaria nana** (Fée) R. Sant.
Floreana: *64132*; San Cristóbal: *Gradstein 63825*; Santa Cruz: *40211*, *40431*. On *Eugenia*, *Coffea*, *Citrus* and *Miconia*, moist zone. !Vezda.

***Tapellaria nigrata** (Müll.-Arg.) R. Sant.
San Cristóbal: *63763 p.p.* (with *Lopadium foliicola*), *63769*. !Vezda. On *Citrus* and mango leaves.

Teloschistes flavicans (Sw.) Norm.
Española, Floreana, Isabela, Pinzón, Rábida, San Cristóbal, San Salvador, Santa Cruz: *Lich. Exs. COLO 108*; Santa Fé, Wolf. Common on twigs in the cactus forest, infrequent in moist zone. Thallus fruticose, orange, terete, with slit-soralia, usually sterile; apothecia orange with thalline rim.

***Tephromela atra** (Huds.) J. Hafelln. *Lecanora atra* (Huds.) Ach.
San Salvador: on *Bursera*, *Pike 56155* (cortex UV-, medulla UV+). The genus is presently under study by Hafellner.

***Trapelia coarctata** (Sm.) Choisy. *Lecidea coarctata* (Sm.) Nyl.
Santa Cruz: base of El Puntudo, west of Cerro Crocker, *55385*. The only common and well-developed crustose lichen on the almost constantly wet rocks of the summit grassland. Thallus of minute scattered white squamules.

***Trapeliopsis granulosa** (Hoffm.) H. T. Lumbsch. *Lecidea granu-*

losa (Hoffm.) Ach.
Santa Cruz: on plant debris, saddle between El Puntudo amd Cerro Crocker, 700 m.s.m., *63337*.

***Tricharia vulgaris** (Müll.-Arg.) R. Sant.
Santa Cruz: on leaves of *Coffea*, Horneman garden, *40433 p.p.* (with *Aspidophyllum fugiens*). !Vezda

***Trypethelium eluteriae** Spreng.
Santa Cruz: *40410*; San Salvador: *Pike 56161*. Common on *Bursera* in the cactus forest. Thallus pale, gray or yellowish; stroma high, rounded, more or less constricted at base, discrete, with numerous punctiform ostioles; interperithecial areas yellow, K+ violet.

***Trypethelium mastoideum** Ach.
Fernandina: *Cavagnaro 40476, 40484*; San Salvador: *Pike 56189*; Santa Cruz: *40409, 54833*. Common on smooth-barked trees (*Bursera, Ochroma, Xanthoxylum*). Thallus smooth, yellowish, the stroma dark, strongly contrasting, raised but not constricted at base, with numerous punctiform ostioles; perithecia black, but yellow areas tending to turn orange.

***Trypethelium ochroleucum** (Eschw. *in* Mart.) Nyl.
Fernandina: *Cavagnaro 40478*; Santa Cruz: *40051, 40411, 40557, 40612, 54824*; San Salvador: *Pike 55226*. Common on *Bursera*, *Psidium*, *Piscidia*, *Xanthoxylum* in the cactus forest. Thallus yellowish, covering large areas of bark as if painted on; perithecia in clusters in slightly raised stromae, not constricted at base, the ostioles black.

***Trypethelium tropicum** (Ach.) Müll.-Arg. *Zignoella magnoliae* Tracy & Earle, *Z. lichenoides* von Hoehnel, *Z. nobilis* Rehm, acc. to Rogerson (1965 *in litt.*). Possibly not a lichenized fungus.
Floreana, *62990*; Santa Cruz: on dead termite-ridden tree, moist zone below Bella Vista, *40209, 40341, 41200*. On *Bursera*, *Citrus*, *Jatropha curcas* fences, moist zone. Thallus smooth, pale; fruits cannon-ball-round, black, in chains, with prominent pale ostiole.

***Usnea antillarum** (Vain.) Zahlbr.
Fernandina: *Cavagnaro 40441*; Pinzón: *Cavagnaro 40050, 40518*; Santa Cruz: *63311, Stewart 404*; Santa Fé: *Koford 40790*. Stout, branched from the base, green to pale green, cortex and medulla very thin, the axis very thick, excavate inside; soredia arising commonly along the smaller branches as thin eruptive

sites, the soredia soon becoming isidiate and spinuliform, some times the thallus wholly isidiate.

Usnea arthroclada Fée
Fernandina: *Snodgrass & Heller* (FH); Isabela: *Stewart 408*; Pinta: *D. Weber 55223*; San Salvador: *Pike 56190*. Infrequent on *Bursera* in the Transition zone. Thallus long, pendulous, terete, annularly cracked, lacking papillae, soredia, or isidia; stems sparsely dichotomous, the branches closely parallel so that the stems appear simple; no pseudocyphellae; main branches with many perpendicular short branchlets; medulla K+ red.

***Usnea cladocarpa** Fée
Española: *Itow 40735, 40769*; Floreana: *Itow 44003*; Santa Cruz: *40078, Lich. Exs. COLO 507*. On coastal shrubs and *Bursera*. Thallus less than 3 cm, little branched, stout, with thick stems (1.5-2.0 mm), papillose and ciliate; apothecia cup-like, ours with short cilia; soredia absent; plants sometimes degenerate and foveate, medulla K-.

***Usnea paradoxa** (Zahlbr.) Mot.
Santa Cruz: *Kastdalen 40029*; *Lich. Exs. COLO 366*. On shrubs in moist areas (the tortoise ponds near Las Casitas). Thallus very long and essentially unbranched except for the short secondaries; main stem sharply angular, 2 mm wide or more, secondary branchlets sorediate; medulla K+ yellow becoming blood-red.

***Usnea rubiginea** (Michx.) Mass. *U. rubescens* Stirt.
Española, Floreana, Pinzón, Rábida, San Cristóbal, San Salvador, Santa Cruz, Santa Fé. Thallus bushy-branched, cortex with red spots or totally red; medulla white, K+ yellow becoming red; branchlets with fine cylindric isidia and soredia. Fertile specimens, not mentioned by Motyka, were collected on Pinzón: *40152, 40496, 41143*, and Floreana: *40452*, and are essentially esorediate.

***Xanthoparmelia subramigera** (Gyelnik) Hale. *Parmelia subramigera* Gyelnik
Pinzón: *Dawson 40904*; Santa Cruz: *40858, 40923*. !Hale. Frequent on rocks in the cactus forest. Thallus yellow-green, isidiate.

***Xanthoria candelaria** (L.) Kickx
Isabela: *63261*; Santa Cruz: very rare, on *Piscidia*, *40564*; on *Bursera*, *40361*. Thallus orange, forming appressed sterile laciniae with sorediate apices.

REJECTED REPORTS, SYNONYMS AND MISAPPLIED NAMES

Alectoria sarmentosa Ach. A misidentification of *Ramalina usnea.* See discussion in Weber (1966, p. 196).

Anaptychia leucomelaena: see *Heterodermia leucomela*

Anaptychia podocarpa (Bél.) Trev. Reported by Dodge (1936). The specimens belong to *Heterodermia comosa.*

Arthonia cinnabarina (DC.) Wallr. Farlow (1902) = *A. gregaria.*

Arthonia nivea Willey, Synops. Gen. *Arthonia*, p. 5. 1890.

The holotype collection is "*Galápagos, Hassler Exped.*" (!US), on smooth bark, evidently *Bursera.* Since the "Hassler" expedition covered a greater area than Galápagos and several collections have been of species that for reason of non-volcanic substrate could not possibly have come from the islands, it seems best to delete this species from the list until verified collections are forthcoming. *Arthonia* is a very common genus on the islands, and I have many collections, but monographic study is necessary for determinations.

Buellia umbrina Malme: Dodge (1936). The specimen is *Taylor 47874g* (FH) in the packet of "*Caloplaca muelleri*". This is a *Buellia*, and is matched by *COLO 40860*, *Buellia indet.* Thallus brown, epithecium olivaceous, hymenium 40-50mu, IKI+ blue, K=, hypoth. pale brown, IKI+ blue, exciple brown to pale within, spores brown, 2-celled, 9/x5mu, thick-walled with wide septum; thallus Pd+ yellow-orange, medulla K+ yellow to red, C-, Pd-, IKI-. Neither of these specimens matches Malme's description. The medulla in B. umbrina is K-.

Buellia xanthinula (Müll.-Arg.) Malme was reported by Dodge (1936) from a specimen: *Taylor 874d* from Gardner Islet. The specimen is *Buellia straminea.*

Caloplaca elegans (Link) Th. Fr. This was reported by Dodge (1936) from San Salvador: *Taylor 859* (MO in 1965). The specimen is isidiate and belongs to *Caloplaca isidiosa* (Vain.) Zahlbr.

Caloplaca muelleri (Vain.) Zahlbr. Reported by Dodge (1936). The specimen (*Taylor 874b*) comprises the following: *Caloplaca isidiosa*, *Buellia straminea*, *Buellia "umbrina"*, *Lecidea oreinoides* (not reported by Dodge although it dominates the packet), *Diploschistes actinostomus* (reported by Dodge as *Leptotrema* species, immature), and a species of *Dirinaria*.

Caloplaca murorum (Hoffm.) Th. Fr. Reported by Stewart (1912) as *Placodium murorum*, the specimen was undoubtedly *C. isidiosa*, although it was not located at FH.

Caloplaca rugulosa (Nyl.) Zahlbr. Reported by Dodge (1936) from Floreana, *Taylor 859*. The specimen could not be found either at FH or MO. It should be rejected because of the general unreliability of Dodge's determinations.

Cladonia chlorophaea (Flk.) Spreng. Reported by Weber (*Lich. Exs. COLO 139*). The specimens belong to *C. balfourii*.

Cladonia fimbriata (L.) Fr. Reported by Stewart (1912). The specimens belong to *C. pityrea*.

Cladonia furcata f. adspersa Flk. Reported by Stewart (1912). The specimens belong to *C. pityrea*.

Cladonia galapagosensis Ahti= *Cladina confusa*

Cladonia polia R. Sant. Reported by Weber (*Lich. Exs. COLO 106*). = *Cladina confusa*.

Cladonia pycnoclada, reported by Farlow (1902) and Stewart (1912). The specimens are *Cladina confusa*.

Coenogonium sp. Reported by Stewart (1912). The specimen is not *Coenogonium* but a green algal scum occurring on shore shrubs.

Cora pavonia (Sw.) Fr. = *Dictyonema montanum*

Dictyonema sericeum. Reported by Howell (1942). The specimens are *D. guadeloupense*.

Chiodecton sanguineum (Sw.) Vain. = *Herpothallon sanguineum*

Dirina herrei A. Zahlbr. = *D. approximata*.

Lecanora glaucovirens Tuck., Proc. Amer. Acad. 12:172. 1877. The Type: *Hassler Expedition* (FH) consists of four pieces of smooth bark, each with a plaque. The thallus is greenish-gray, grading at the margin to a distinctly pale prothallus; the apothecia are pruinose. Microscopic analysis shows, however, that this is not a *Lecanora*; the rim, is falsely lecanorine as in *Lecidea granifera* Ach., but in contrast to the latter, the hypothecium is hyaline. The spores are 10-12 x 6-7mu. Disposition of this taxon await study of the South American Lecideae. In the absence of any later collections, I doubt that this lichen really came from Galápagos.

Leptotrema mastoideum Müll.-Arg. The specimen (*Taylor 903*) from Floreana (!MO), reported by Dodge (1936) is *Diploschistes scruposus*.

Pannaria molybdaea (Pers.) Tuck. = *Coccocarpia palmicola*.

Parmelia camtschadalis Eschw. The specimens reported by Stewart (1912) belong to *Everniastrum vexans*.

Parmelia latissima Fée. Reported by Stewart (1912). The specimens (FH) belong to *Parmotrema tinctorum*, *P. subcrinita*, *P. endosulphurea*, and *P. cristifera*!

Parmelia perlata Kremp. Reported by Farlow (1902) and Stewart (1912). The specimens belong to *Parmotrema cristifera*.

Parmelia soyauxii Müll.-Arg. Reported by Dodge (1936). Th specimen was not found at FH or MO. This Dodge determination is not to be accepted.

Pertusaria colobina Tuck. The type is a collection from the Hassler Expedition. Santesson examined it and found that on the four pieces of bark, marked a,b,c,d, were (a and d) *Coccotrema granulata* (Hook. *f.* & Tayl.) R. Sant., and (b) *Lepolichen coccophorus* (Mont.) Trev. It is doubtful, since a and b are labelled "Galápagos" that there is any *Pertusaria* here at all, further doubtful that any of the pieces came from Galápagos. In the packet is an annotation "*Lepolichen colobinus* (Tuck.) G. T. Johnson". Tuckerman's handwritten notes read: "sp 8.nae in ellipt , simplice (*Pertusaria*) 46-56/23-25mu iis lich. u. i mm similis. *Hassler Exped. T. Hill*". Santesson agrees that the species present are distinctive Chilean species and could not have been taken on Galápagos. All Hassler Expedition "Galápagos" collections, unless re-collected on Galápagos, should be regarded as extremely doubtful records.

Physcia adglutinata (Flk.) Nyl. Reported by Dodge (1936) from Isabela (*Taylor 853*). The specimen is a fragment of *Dirinaria sp.*, on coastal rock with bits of *Buellia straminea*].

Physcia aegialita (Ach.) Nyl. Reported by Dodge (1936). = *Dirinaria aegialita.*

Physcia alba (Fée) Müll.-Arg. Reported by Dodge (1936) from Hood (*Taylor 874e*). The fragment is in a packet of "*Caloplaca muelleri*", and is a *Dirinaria sp.*].

Physcia aspera H. Magn. A variety of taxa have been reported under this name. *Stewart 357* (FH) was cited by Thomson (1963), but it matches *COLO 40110, Dirinaria caesiopicta.*

Physcia leucomela (L.) Michx. = *Heterodermia leucomela.*

Physcia picta (Sw.) Nyl. Reports (Stewart 1912, Thomson 1963) are misdeterminations of *Dirinaria applanata* and *D. leopoldii.*

Placopsis cribellans (Nyl.) Räsanen. Reported from a Hassler Expedition collection. The specimens must have come from Tierra del Fuego. See discussion in Weber (1966, p. 196).

Pseudocyphellaria xantholoma (Del.) Dodge = *P. mougeotiana* var. *aurigera.*

Pyxine glebosa Tuck., Synops. N. Amer. Lich. 1:79. 1882. "Galápagos Islands, *Dr. Hill in Hassler Exp.*" Contrary to Imshaug's annotation and his notes in Bryologist 58:283. 195, the type specimen (!FH) is *Pyxine* and not *Buellia.* Superficially it is similar to *P. pringlei* but UV-, there is a well-developed pulpa or hypothecium as well as a brown stipe. The epithecium and stipe in *P. pringlei* are K+ violet, in *P. glebosa* K-. The spores are similar to those of *P. pringlei* (12-17[20]x5-7mu) and mischoblastiomorphic. The apothecia are prominently enveloped by a pseudothalloid margin. According to Imhaug's treatment this would come to *P. endoleuca* (Müll.-Arg.) Vain. However, the questionable collecting data and the fragmentary condition of the specimens argue against synonymizing a well-established taxon. Nothing like it has been collected recently.

Ramalina dasypoga Tuck. The report is based on *Taylor 911* (Dodge 1936). Taylor's collection (MO) comprises two packets of *R. furcellata* and one of *R. usnea.*

Ramalina farinacea Ach. Reported by Dodge (1936). The specimens represent a species, probably *R. furcellata*), with terete thalli and globular soralia. Magnusson saw these specimens but did not annotate them. *Stewart 371* (FH) was annotated by Magnusson as "*R. complanata var.*"]

Ramalina indica Fr. Reported by Farlow (1902) and Stewart (1912) and Dodge (1936) from a specimen from Floreana (!FH) collected by N. J. Andersson. The specimens fit my concept of *R. complanata sens. lat.*

Ramalina interponens Nyl. The report by Dodge (1936) is incorrect. The specimen, *Taylor 873* (!MO), from Gardner Bay, is *R. complanata sens. lat.* Chemical tests have not been made.

Ramalina puiggarii Müll.-Arg. All specimens reported by Dodge (1936) belong to what I am calling *R. linearis*.

Ramalina subasperata Nyl. Reported by Dodge (1936). The specimen represents *R. complanata sens. lat.*

Ramalina subfraxinea Nyl. Reported by Dodge (1936). The specimen represents *R. complanata sens. lat.*

Ramalina usneoides (L.) Howe = *R. usnea*.

Roccella difficilis Darb. This taxon was suspected by Darbishire to be a saxicolous form of *R. babingtonii*. The subsequent report by Dodge (1936) is incorrect; the cited Taylor specimen *854* (!FH, MO) is *Roccella galapagoensis*.

Roccellodea nigerrima Darb., Ann. Crypt. Exot. 5:153-158. 1932.

The type of the genus and species came from "Galápagos", *J. Hill, Hassler expedition* (herb. Darb., isotype FH). The lichen is extremely similar to *R. galapagoensis* but was said to have had the medulla of older parts black, and apothecia which are irregular in shape (5x1.5 mm), and a colorless "hypothecium" (dark in *Roccella*). Soredia were present. Two Stewart specimens cited by Darbishire (1935) from Española and Floreana are sterile; how these could have been so determined is not clear. Until more material is discovered the identity (and type locality) of this taxon remain a mystery. Perhaps somewhere in the rich (and chemically variable) material of *R. galapagoensis*, some of which is sorediate, may come an answer.

Sticta quercizans Del. Reported by Stewart (1912) = *S. weigelii*.

Teloschistes exilis (Michx.) Vain. Reported by Dodge

(1936). The specimen (*Taylor 865*, FH) is typical *T. flavicans*, sorediate and sterile.

Usnea ceratina Ach. Reported by Farlow (1902) and Stewart (1912). A common waste-basket assignment for unidentifiable tropical *Usnea*. At least one collection, *Stewart 405*, is *U. rubiginea*. Herre noted on the specimens: "None of these remotely resemble *U. ceratina*". A Baur specimen of *U. rubiginea* (FH) was called *U. barbata*. Old identifications of *Usnea*, and many recent ones, including my own, need to be taken with a grain of salt.

Usnea longissima Ach. Reported by Stewart (1912). The specimens belong to *U. amabilis*.

Usnea plicata Hoffm. Reported on the basis of scrappy specimens collected by J. H. Andersson and Charles Darwin. Herre's remarks could apply here as well.

APPENDIX II: NEW COMBINATION

Buellia mamillana (Tuck.) W. A. Weber, **comb. nov.** *Rinodina mamillana* Tuck., Proc. Amer. Acad. 7:226. 1866 (publ. 1868). *Lecidea glaziouana* Kremp., Flora 59:317. 1876. *Buellia glaziouana* Müll.-Arg., Flora 63:19. 1880.

The type (!FH) was collected on Oahu, Hawaii, by Mann. The Galápagos report by Tuckerman (1887) was based on a specimen collected by Hill on the Hassler Expedition. The holotype (!FH) in all respects agrees with *Buellia glaziouana*. Tuckerman probably included this in *Rinodina* due to the false thalloid rim of the apothecium. In section it is not lecanorine. The epithet, *mamillana*, was chosen to denote a rugose-plicate (teratological?) development of the apothecial disk. Tuckerman himself attached little significance to this feature in pointing out that the Galápagos material lacked it. *Buellia glaziouana* has been described as a *Rinodina* several times, viz: *R. thomae* Tuck., *R. contiguella* Vain., and also as *Melanaspicilia*.

Chemically, spot tests of both collections cited by Tuckerman give the thallus K+ yellow wash, Pd+ sordid yellowish, C-. medulla IKI+ blue. Imshaug (1951) pointed out that the type of *B. glaziouana* has an IKI+ blue reaction in the medulla, contrary to statements of Vainio and Malme. Magnusson, in Cat. Lich. Hawaii (1955 p. 386) points out that *Rinodina mamillana* Tuck. has an IKI+ blue reaction in the medulla, contrary to Zahlbruckner's finding.

The specific epithet *mamillana* unfortunately has priority over *glaziouana*, necessitating this new combination.

APPENDIX III

A new species of Stereocaulon

On two occasions between 1964 and 1971, a very strange sterile lichen was collected on bare lave rocks, first by Yale Dawson on Marchena (40905), and later by Larry Pike on San Salvador (55240). These consisted of single, minute cup-shaped gray squamules with upturned margins exposing a white lower cortex. They were obviously juvenile basal squamules but they were much more chondroid than those of any local *Cladonia*. In June, 1976, Harry Sipman collected mature pseudopodetia, which suggested that this was possibly a *Stereocaulon* or a *Gymnoderma*. Study by Dr. Isao Yoshimura determined that it could not be *Gymnoderma*, and that it produced marginal apothecia (no spores were found, however) and rod-shaped pycnidiospores. Morphologically it matched the Beringian Arctic *Stereocaulon wrightii* Tuck. and *S. apocalyptum* Nyl., but whereas these contain atranorine with stictic and lobaric acid, respectively, the Galápagos material contains atranorine with norstictic acid.

Because cephalodia and spores were not found on the Sipman collection, a special trip to Cerro Azul was made in 1984 to collect enough material for the *Lichenes Exsiccati COLO*, with good results. The new species forms masses of crowded pseudopodetia up to 10 mm high on the vertical faces of uncovered lava tubes along the steep upper slopes of the mountain. Cephalodia as well as small numbers of apothecia without well-developed spores were found. The name of the new species commemorates the type locality: Volcán Cerro Azul on Isabela Island.

The occurrence of an Equatorial vicariad species related to two Beringian ones raises the question not only of dispersal but of the time-frame over which evolution of these chemically-diversified species took place. Dispersal seems most likely to have been by birds. Chemical evolution has to have occurred within the lifetime of the Islands, which is estimated from between one and seven million years. Morphologically the three taxa are indistinguishable.

Stereocaulon azulensis Yoshimura and Weber, **sp. nov.**

Thallus primarius concavus, orbicularis, usque ad 1 mm diam, evanescens; pseudopodetia laciniato-ramosis, dorsiventralibus, usque ad 10-15 mm longis, 0.8-2.0 mm latis, marginibus irregulariter crenulatis, paginis dorsalibus corticatis, plus *minusve concavis, griseis, ultimo rimosis, paginis ventralibus ecorticatis, albo-tomentosis, venosis, basin versus nigrescens, K+ lutescentibus, P+ leniter lutescentibus, acido norstictico et atranorin continens. Apothecia sessilibus, marginalibus, usque ad 0.4-0.5 mm diam, lecidiinis; sporae desunt. Pycnidia marginalibus et dorsalibus, ostiolis nigris 0.2-0.3 mm latis, pycnoconidia 4.5-5.0 mu longis, linearibus, rectis interdum arcuatis. Cephalodia atrobrunnea, verrucosa, super phyllocladia, Stigonema continentibus.*

Primary thallus concave, orbicular, up to 1 mm diam, disappearing; pseudopodetia laciniately branched, dorsiventral, up to 10-15 mm long, 0.8-2.0 mm wide, the margins irregularly crenulate; dorsal surface corticate, more or less concave, gray, cracked in age; ventral surface ecorticate, white-tomentose, veined, blackening toward the base, K+ yellow; medulla K+ yellow, P+ weakly yellow; norstictic acid and atranorine present. Apothecia sessile, marginal, up to 0.4-0.5 mm diam, lecidiine; spores not found; pycnidia marginal and dorsal; ostiole black, 0.2-0.3 mm wide; pycnoconidia 4.5-5.0 mu long, linear, straight or sometimes more or less curved. Cephalodia blackish-brown, verrucose, on the phyllocladia, containing *Stigonema*.

HOLOTYPE: ECUADOR. Galápagos Islands. Isla Isabela: Volcán Cerro Azul, south slope above Iguana Cove, 700 m.s.m., on mossy rock, bank of ravine, 17 Jan. 1984, *Weber & Beck , Lich. Exs. COLO 645* (COLO).

ADDITIONAL COLLECTIONS: Isla San Salvador: nearly barren, recent a-a lava flow near James Bay, 27 April 1971, *Pike 2607*; Isabela: Volcán Cerro Azul, 500 msm, 22 June 1976, *Sipman 63507*, 700 msm, *Sipman 63525*.

LITERATURE CITED

Ahti, Teuvo. 1961. Taxonomic studies on reindeer lichens (*Cladonia*, subgenus *Cladina*). Ann. Bot. Soc. "Vanamo" 32:1-160. 44 plates.

Arvidsson, Lars. 1982. A monograph of the lichen genus *Coccocarpia*. Opera Bot. 67:1-96.

Awasthi, D. D. 1975. A monograph of the lichen genus *Dirinaria*. Bibl. Lichenol. 2:1-108.

Brodo, Irwin M. 1984. The North American species of the *Lecanora subfusca* group. Nova Hedw., Beih. 79: 63-285.

Darbishire, O. V. 1935. The Templeton Crocker Expedition of the Calif. Acad. of Sciences, 1932. No. 23. The Roccellaceae... Proc. Calif. Acad. Sci. 21:285-294.

Dodge, Carroll W. 1935. Lichenes. In H. K. Svenson. Plants of the Astor Expedition, 1930 (Galápagos and Cocos Islands). Amer. J. Bot. 22:221.

________________. 1936. Lichens of the Allan Hancock Expedition of 1934, collected by Wm. R. Taylor. Hancock Pacific Expeditions 3(3):33-46.

Farlow, W. G. 1902. Lichens, p. 83-89, In: B. L. Robinson, Flora of the Galápagos Islands. Proc. Amer. Acad. Arts Sci. 38.

Galloway, D. J. & P. M. Joergensen. 1975. *Erioderma sorediatum*, a new lichen from New Zealand. Lichenologist 7:139-142.

Gradstein, S. R., & William A. Weber. 1982. Bryogeography of the Galápagos Islands. J. Hattori Bot. Lab. 52:127-152.

Hale, Mason E. 1984. The lichen line and high water levels in a freshwater stream in Florida. The Bryologist 87: 261-265.

Hamann, Ole. 1986. The El Niño influence on the Galápagos vegetation. pp. 299-330 in Robinson & del Pino (eds.). El Niño en las Islas Galápagos. El evento de 1982-1983.

Hooker, Joseph Dalton. 1846. An enumeration of the plants of the Galápagos Archipelago, with descriptions of those which are new. Trans. Linn. Soc. 20:163-233.

Howell, John Thomas. 1932. Up under the Equator. Sierra Club Bull. p. 79-82.

Imshaug, Henry A. 1951. The lichen-forming species of the genus *Buellia* occurring in the United States and Canada. Unpublished Ph.d. thesis, 217 pp. University Microfilms.

________________. 1955. The lichen genus *Buellia* in Central America. The Bryologist 58:277-287.

________________. 1955a. The lichen genus *Buellia* in the West Indies. Farlowia 4(4):473-512.

Magnusson, A. H. 1955. A catalogue of the Hawaiian lichens. Ark. f. Bot. (2) 3(no.10):1-402. 8 plates.

Malme, G. O. 1927. *Buelliae itineris Regnellianae primi.* Ark. f. Bot. 21A (14):1-42.

Poelt, J., & A. Vezda. 1981. Bestimmungsschlüssel europäischer Flechten. Erganzungsheft II. 390 pp. J. Cramer.

Redinger, Karl M. 1936. *Thelotremaceae Brasilienses* ... Ark. f. Bot. 28A (8):1-122.

Santesson, R. 1939. Über die Zonationsverhältnisse der lacustrine Flechten einiger Seen in Anebodagebiet. Medd. Lunds Univ. Limnolog. Inst. 1:1-70.

Stewart, Alban. 1912. Notes on the lichens of the Galápagos Islands. Proc. Calif. Acad. Sci. (4) 1:431-446.

Svenson, Henry K. 1935. Plants of the Astor Expedition, 1930 (Galápagos and Cocos Islands). Amer. J. Bot. 22:208-277.

_______________. 1963. Opportunities for botanical study on the Galápagos Islands. Occas. Pap. Calif. Acad. Sci. 44:53-58.

Tehlér, Anders. 1983. The genera *Dirina* and *Roccellina* (Roccellaceae). Opera Bot. 70:1086.

Thomson, John W. 1963. The lichen genus *Physcia* in North America. Nova Hedwigia, Beih. 7:1-172. 47 maps, 25 plates.

Usinger, Robert Leslie. 1972. Autobiography of an entomologist. Mem. Pacific Coast Ent. Soc. Vol. 4. 330 pp. California Academy of Sciences.

Weber, William A. 1966. Lichenology and bryology of the Galápagos Islands, with check lists of the lichens and bryophytes thus far reported. Pp. 190-200 [in] Robert I. Bowman (ed.). The Galápagos. Univ. of California Press.

_______________. 1971. Four new species of *Buellia* from western North and South America. The Bryologist 74:185-191.

_______________. 1976. Additions to the bryophyte flora of the Galápagos Islands. Lindbergia 4:76-79.

_______________. 1981. Lichenes Exsiccati distributed by the University of Colorado Museum, Boulder, Fascicles 1-15, Nos. 1-600, 1961-1979. Mycotaxon 13:85-104.

_______________. 1984. Galápagos cryptogams and the 1983 record El Niño. Internat. Lichen Newsletter 17:15-17.

_______________. 1984a. Bryophytes and lichens of the Galápagos Islands. National Geographic Society Research Reports for 1975, 16:781-790.

_______________, & Hans Beck. 1986. Effects on cryptogamic vegetation (lichens, mosses and liverworts). Chapter 3, in El Niño en las Islas Galápagos: El Evento de 1982-1983. 16 pages, 3 plates. Charles Darwin Foundation.

_______________, & S. R. Gradstein. 1984. Lichens and bryophytes. Chapter 5 [in] The Galápagos Islands. Pergamon Press, Key Environment Series.

_______________, S. R. Gradstein, J. Lanier & H. Sipman. 1977. Bryophytes and lichens of the Galápagos. Noticias de Galápagos 26:7-11.

_______________, & J. Lanier. 1977. Lichens in the Galápagos Islands. 20 pp. (in Spanish). Charles Darwin Research Station.

Wiggins, Ira L., & Duncan M. Porter. 1971. Flora of the Galápagos Islands. 998 pages, 96 plates, 268 figs. Stanford.

Willey, H. 1890. A synopsis of the genus *Arthonia*. Privately printed.

MYCOTAXON

Vol. XXVII, pp. 499-502 October-December 1986

PLATYGLOEA ACANTHOPHYSA, A NEW SPECIES WITH SINGLE STERIGMATE BASIDIA AND ACANTHOPHYSES

HAROLD H. BURDSALL, JR.

Center for Forest Mycology Research

Forest Products Laboratory[1]
USDA, Forest Service
Madison, WI 53705-2398

The genus Platygloea Schröter in the Heterobasidiomycetidae is distinguished by a well-developed probasidium that produces a cylindrical, transversely septate metabasidium. The basidiospores germinate by repetition. However, several species of Platygloea form only an aseptate metabasidium or a metabasidium with a single septum, e.g., Platygloea unispora Olive (1944) and P. mycophila Burds. et Gilbn. (1974). Larsen (1984) indicated that Laeticorticium simplicibasidium Linds. et Gilbn. (Lindsey and Gilbertson 1977) is probably a single sterigmate member of the Auriculariaceae as is Itersonilia perplexans Derx. Two species of Septobasidium Pat. also possess unisterigmate basidia, but they have a constant association with scale insects.

The new species of Platygloea described here with an aseptate metabasidium producing a single sterigma was collected in northern Wisconsin in 1973. Further collecting in similar habitats has not provided additional specimens of this species.

---

[1] Maintained in cooperation with the University of Wisconsin.

Platygloea acanthophysa Burds. sp. nov. Fig. 1

Basidiocarpo late effuso; hyphis fibulatis; acanthophysibus variiformibus vel pyriformibus, 15-25 x 8-10(-13) µm, digitiformibus processibus usque 6 µm longis; basidiis aseptatis, unisterigmatibus, 33-45 x 8-10(-13) µm; basidiosporis late ellipsoideis vel subglobosis, 13-16 x 12-13 µm, apiculis 2.5 x 2.5 µm, inamyloideis; acyanophilis.

Holotypus.--FP 101129, on Tsuga canadensis L., Kemp Biological Station, Minocqua, Oneida County, Wisconsin, 10 VIII 1973, leg. F. F. Lombard et R. G. Payne, in CFMR conservatum.

Basidiocarp annual, broadly effuse, a thin vernicose film, adherent, fertile area continuous, smooth to slightly pubescent, pale gray; margin abrupt, not differentiated.

Hyphal system monomitic, subiculum an agglutinated textura intricata, hyphae (Fig. 1C) 3-6 µm diam., thin-walled or with slight wall thickening, hyaline, smooth, with rare branching, nodose septate; subhymenium not differentiated; acanthophyses (Fig. 1A) variously swollen to pyriform, 15-25 x 8-10(-13) µm, hyaline, thin-walled or with slight wall thickening, digitate processes up to 6 µm long, 0.5-1 µm diam., nodose septate at base; basidia (Fig. 1B), including sterigmata, 33-45 µm long; probasidium poorly differentiated but usually with slight wall thickening, 8-10(-13) µm wide, hyaline, smooth or with acanthophysoid processes; basidiospores (Fig. 1D) broadly ellipsoid to subglobose, 13-16 x 12-13 µm, with apiculus up to 2.5 x 2.5 µm, hyaline, thin-walled, smooth, nodose septate at base, not staining in Melzer's reagent, acyanophilous, germinating by repetition.

Etymology.--From the acanthophyses present in the hymenium.

Discussion.--Although this species is known from only one collection, it is so distinctive that it deserves to be recognized. It is unique not only in the genus Platygloea but throughout the Heterbasidiomycetidae in possessing acanthophyses such as are found in the Aleurodiscoideae. The digitate processes are also found on some basidia. In addition to the acanthophyses, the single-spored basidium and large broadly ellipsoid to subglobose basidiospores are distinctive.

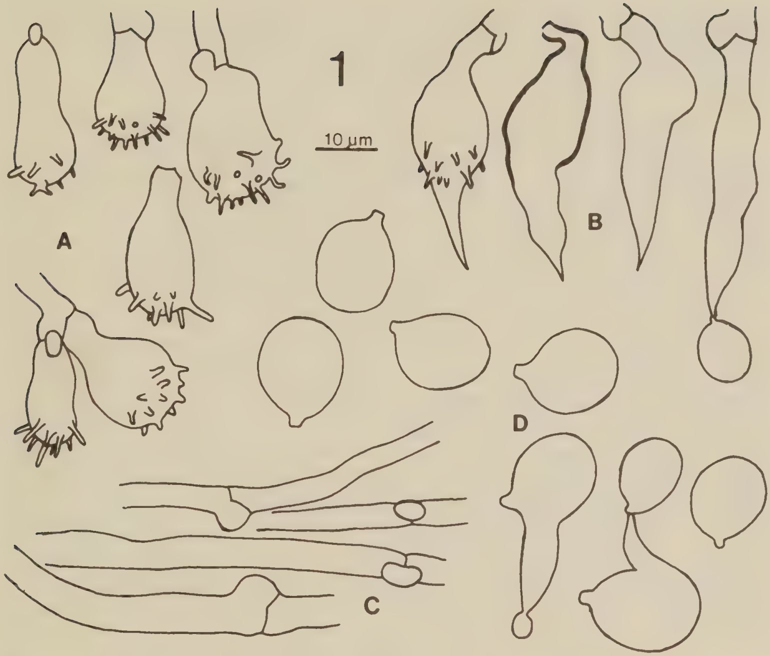


Fig. 1. Line drawings of microscopic structure of P. acanthophysa. A. acanthophyses; B. unisterigmate basidia; C. subicular hyphae; D. basidiospores, some showing germination by repetition. (ML86 5208)

Platygloea acanthophysa, with basidiospores 12-18 x 9-14 µm, is distinguished because of its pustulate basidiocarp, the presence of simple or somewhat branched hyphidia, and a long narrow basidium 61-83 x 6.1-7.6 µm. Laeticorticium simplicibasidium is distinguished from P. unicornis in possessing globose basidiospores 9-11 µm broad, basidia up to 125 x 3-5 µm. Itersonilia perplexans Derx. has similar morphology but differs in possessing basidiospores (conidia of Olive 1952) measuring "7.6-10.6 x 12.2-18 µ" (Olive 1952). None of the species mentioned previously possesses acanthophyses found in P. unicornis.

The two one-spored Septobasidium species have a constant association with both living trees and scale insects, neither of which is associated with Platygloea *acanthophysa*. Morphological differences between *P. acanthophysa* and the *Septobasidium* species readily distinguish them (Couch 1938).

The generic disposition of *P. acanthophysa* was not straightforward. There was the possibility that it was a one-spored species in the Tremellaceae. At the suggestion of Dr. Kenneth Wells, University of California, Davis, CA, and Dr. Franz Oberwinkler, University of Tubigen, West Germany, I examined the septal apparatus by transmission electron mycroscopy. The septa were distinctly simple with no indication of a dolipore. This is the same septal type present in the genus *Platygloea*. Species in the Tremellaceae possess dolipore septa. Thus, the genus *Platygloea* is the appropriate placement.

At the Forest Products Laboratory, Dr. M. J. Larsen prepared the Latin diagnosis, Mr. T. A. Kuster performed the transmission electron mycroscopy, and Mrs. F. F. Lombard contributed a valuable manuscript review. Dr. E. L. Stewart, University of Minnesota, and Dr. Kenneth Wells also contributed valuable manuscript reviews.

LITERATURE CITED

BURDSALL, H. H., Jr., and R. L. GILBERTSON. 1974. A new species of Platygloea occurring on *Peniophora tamaricicola* in Arizona. *Mycologia* 66:702-706. COUCH, J. N. 1938. The genus *Septobasidium*. Univ. of North Carolina Press, Chapel Hill. 480 p. LARSEN, M. J. 1984. Notes on laeticorticioid fungi. *Mycologia* 76:353-355.
LINDSEY, J. P., and R. L. GILBERTSON. 1977. New species of corticioid fungi on quaking aspen. *Mycotaxon* 5:311-319.
OLIVE, L. S. 1944. New or rare heterobasidiomycetes from North Carolina I. *J. Elisha Mitchell Sci. Soc.* 60:17.
OLIVE, L. S. 1952. Studies on the morphology and cytology of *Itersonilia perplexans* Derx. *Bull. Torrey Bot. Club* 79:126-138.

MYCOTAXON

Vol. XXVII, pp. 503-506 October-December 1986

MACROCHEMICAL COLOR REACTIONS OF MACROMYCETES

II. Chemical properties and systematic position of Bondarzewia mesenterica

Harald M. Frank
Amthorstr. 5, Gera 6500, DDR

The discussion about the systematic position of *Bondarzewia* Sing. was renewed by Singer (1984) recently. Especially the similarity of the spore ornamentation has lead to the assumption of common ancestry of Russulaceae and Bondarzewiaceae. Newly recorded lactiferous species of *Bondarzewia* and parasitic species of *Lactarius* Pers. (Kreisel 1983, Singer 1984) are further reasons. Carrying out systematic examinations of the macrochemical behavior *Bondarzewia mesenterica* (Schaeff.)Kreisel (hitherto known as *Bondarzewia montana* (Quel.)Sing.) was found to give a reaction pattern which seems to support the close relation between these two families.

Only fresh specimen of single collections were tested. The selection of the reagents, their concentration and the use of the color atlas of Küppers (1984) were founded in detail by Frank (1987). Colors were regarded in each case to be a composition of yellow (Y), magenta red (M) and cyan blue (C). To simplify typing the format used here is 30.10.70 which means $Y_{30}M_{10}C_{70}$ or 30% saturation in Y, 10% in M and 70% in C.
The abbreviations "n.ex." and "-" mean that the fruit body was not examined and no change occured compared with a piece exposed to air only. The nomenclature of *Russula* Pers. is according to Kreisel (1983).
The reagents are KOH, H_2SO_4 = H2S, $FeSO_4$ = FES, $AgNO_3$ = AGN, phenol = PHE, 1-naphthol = NAP, benzidine = BEN, guaiac = GUA, guaiacol = GCL, ninhydrin = NIN, aniline = ANI, formalin = FOR, Lugol = LUG and sulfovanillin = SV.

Russula caerulea (Pers.)Fr. emend. Cke. : KOH -, H2S -, FES -, AGN -, PHE dark brown 55.85.80, NAP black violet 30.80.90, BEN bright greenish blue 25.00.99, GUA dark blue green 30.30.99, GCL bright orange 70.50.00, NIN -, ANI -, FOR -, LUG -, SV -, air -.

Russula atropurpurea (Krbh.)Britz. : KOH yellow 30.03.00, H2S greyish 05.10.20, FES greyish pink 10.30.10, AGN -, PHE brown 35.50.40, NAP pale lilac 05.25.10, BEN olive 80.20.40, GUA bright blue 25.10.90, GCL apricot 35.25.00, NIN -, ANI -, FOR -, LUG yellow brown 70.50.40, SV violet 10.60.65, air -.

Russula chloroides Krbh. : KOH yellowish 20.00.00, H2S -, FES rapidly pink 15.30.00, AGN -, PHE vinaceous to dark brown 70.80.60, NAP blackish violet 20.80.60, BEN instantly bright blue 10.00.80, GUA very rapidly dark blue green 30.20.80, GCL red brown 60.60.30, NIN slowly pinkish 10.20.00, ANI -, FOR -, LUG greenish brown 60.50.70, SV n.ex., air -.

Russula fellea (Fr.)Fr. : KOH strong yellow 60.00.00, H2S dun 40.40.60, FES pale greyish pink 10.10.05, AGN strong chocolate 50.80.80, PHE red brown 60.60.40, NAP -, BEN ochraceous brown 35.50.40, GUA dull dark green 50.35.85, GCL red brown 60.60.40, NIN -, ANI -, FOR -, LUG yellowish brown 90.65.65, SV purple 25.75.55, air -.

Russula ochroleuca (Pers.)Fr. : KOH yellowish 20.00.00, H2S -, FES greyish pink 10.20.05, AGN pale pink 10.10.00, PHE dark brown 50.70.80, NAP dark violet 30.70.80, BEN instantly light blue 10.00.65, GUA instantly blue green 30.00.75, GCL bright red brown 70.80.60, NIN -, ANI pink grey 30.20.20, FOR pale pink 10.10.00, LUG -, SV n.ex., air -.

Russula virescens (Schaeff.)Fr. : KOH yellowish 20.00.00, H2S pale yellowish 10.00.00, FES rather instantly pink 15.30.00, AGN -, PHE greyish pink 15.25.03, NAP greyish lilac 05.20.05, BEN apricot 50.10.00, GUA rapidly dark blue green 30.30.99, GCL pinkish orange 25.40.00, NIN very pale grey 05.05.05, ANI yellowish 20.00.00, FOR -, LUG bright yellow 70.05.05, SV bright purple 03.50.03, air -.

Russula cyanoxantha (Schaeff.)Fr. : KOH -, H2S -, FES greyish 10.05.10, AGN pale pinkish grey 10.10.05, PHE vinaceous brown 70.85.60, NAP violet 10.45.45, BEN instantly bright blue 10.00.99, GUA instantly bright blue 25.00.99, GCL vinaceous lilac 25.50.20, NIN very pale bluish violet 05.10.20, ANI ochraceous pink 35.25.00, FOR -, LUG -, SV n.ex., air -.

Russula heterophylla (Fr.)Fr. : KOH yellowish 20.00.00, H2S -, FES instantly reddish 15.30.00, AGN yellowish creme 30.10.00, PHE rapidly red brown 70.70.50, NAP rapidly violet 10.45.45, BEN instantly blue 10.30.80, GUA instantly dark blue green 30.30.99, GCL dull yellow 25.10.05, NIN slowly grey 10.05.30, ANI very pale greenish yellow 10.00.05, FOR n.ex., LUG -, SV n.ex., air -.

Russula xerampelina (Schaeff.)Fr. : KOH yellow 50.00.00, H2S -, FES greyish green 30.10.40, AGN greyish pink 10.30.10, PHE dark red brown 70.80.60, NAP dark violet 30.70.80, BEN instantly bright blue 10.00.90, GUA rapidly dark green 50.35.85, GCL red 15.55.05, NIN greyish pink 10.20.00, ANI bright red 45.75.05, FOR greyish pink 10.20.00, LUG -, SV -, air -.

Bondarzewia mesenterica : KOH golden 55.25.00, H2S grey 20.10.20, FES -, AGN -, PHE greyish 10.10.10, NAP rapidly violet 00.50.50, BEN instantly bright blue 10.00.99, GUA rapidly dark blue green 30.30.99, GCL rapidly bright orange red 70.60.00, NIN -, FOR -, LUG instantly blackish brown 80.90.90, SV dark violet 30.70.80, air -.

The species of Russulaceae are very profitable objects for agaricologists due to their various behavior against different reagents. The strong discoloration after stressing with oxidase-sensitive molecules like phenol, benzidine, 1-naphthol, guaiac and guaiacol is a rather unique phenomenon comparable at the present stage of knowledge only with species of the genus Agaricus L. In a representative 72 specimen sample Marr (1979) found that the combination of laccase and tyrosinase is a typical and constant feature of the 13 Russulaceae species examined. Additionally these specimen represent about 90% of the specimen with the coupled oxidases.

Therefore it is interesting to note that Bondarzewia mesenterica is very similar to the majority of the Russula species choosen here. The white fruit body contains larger amounts of different oxidases and reacts with sulfovanillin. The latter is according to Camazine and Lupo (1984) probably an indicator of the pungent principle (acrid tasting aldehydes) common and typical in Russulaceae. The compounds detected here are not only secondary metabolites but reflect as well physiological potency as ecological requirements.
It seems to be justifiable to plead for the concept of Singer (1984).
Differences within the genus Russula e.g. the ochraceous color of Russula fellea after applying benzidine (an extraordinary reaction which was already described by Micka and Klan 1980) should be understood as a result of phylogenetic divergence.

The results support the authors intention in 2 respects: macrochemical color reactions are usefull to distinguish closely related species (e.g. Russula fellea and Russula ochroleuca) and/or they can be used as arguments in establishing phylogenetic pathways.

Acknowledgement

I wish to thank R. Conrad and F. Gröger for their help in collecting and examining material.

Literature

Camazine, S. & A.T. Lupo, Jr. 1984. Labile toxis compounds of the Lactarii: The role of the laticiferous hyphae as a storage depot for precursors of pungent dialdehydes. Mycologia 76(2): 355-358.

Frank, H. 1987. Makrochemische Farbreaktionen bei Großpilzen I. Voraussetzungen für eine systematische Untersuchung. Z. Mykol., accepted for publication.

Kreisel, H. 1983. Michael-Hennig-Kreisel, Handbuch für Pilzfreunde, Bd. 5. Fischer Verlag, Jena. 408 p.

Küppers, H. 1984. DuMont's Farbenatlas. DuMont Buchverlag, Köln. 164 p.

Marr, C.D. 1979. Laccase and tyrosinase oxidation of spot test reagents. Mycotaxon 9: 244-276.

Micka, K. & J. Klan. 1980. Chemical spot tests of macromycetes with benzidine. Česka mycologie 34(2): 74-81.

Singer, R. 1984. Tropical Russulaceae II. Lactarius section Panuoidei. Nova Hedwigia 40: 435-442.

MYCOTAXON

Vol. XXVII, pp. 507-550 October-December 1986

EAST AFRICAN RUSTS (UREDINALES), MAINLY FROM UGANDA
5. ON FAMILIES BELONGING TO GAMOPETALAE

Halvor B. Gjærum

Norwegian Plant Protection Institute
P.O. Box 70, N-1432 ÅS-NLH, Norway

Summary

Seventy-one rust taxa on host families belonging to Gamopetalae (Sympetalae) of the Dicotyledones are recorded. Ten species are described as new, viz. *Aecidium aspiliae* on *Aspilia pluriseta*, *A. echuyaënse* on *Helichrysum foetidum*, *A. haplocarphae* on *Haplocarpha rueppellii*, *Puccinia artemisiae-afrae* on *Artemisia afra*, *P. crassocephali* on *Crassocephalum aframontanum*, *P. tetradeniae* on *Tetradenia riparia*, *Uredo hypoëstis-verticillaris* on *Hypoëstes verticillaris*, *U. isoglossae* on *Isoglossa substrobilina*, *U. leucadicola* on *Leucas martinicensis*, *Uromyces sasaënsis* on *Valeriana volkensii*. *Uredo paederiae* on *Paederia foetens* is new to Africa. Eighteen species are reported as new to Uganda, three are new to Kenya, and one to Tanzania.

The main part of material treated was collected by myself in Uganda in 1970 or picked out from herbaria in Kampala and Oslo. For comparison I have borrowed material from Swedish Museum of National History (S), Royal Botanic Gardens, Kew (K), and Commonwealth Mycological Institute (IMI). My thanks are due to the curators of the herbaria mentioned.

During my stay at CMI in 1982, kindly financed by the Norwegian Agency for International Development (NORAD), I also had the opportunity to use their material for comparison, and for which I am most grateful.

Mr. K.A. Lye at the Botanical Institute of the Agricultural University of Norway has kindly helped me with host identifications and Dr. G.B. Cummins, Dept. of Plant Pathology, University of Arizona, Tucson, AZ, and Prof. D.M. Henderson, Royal Botanic Garden, Edinburgh, have critically read the manuscript. I am much indebted for this valuable help.

Finally, I want to thank heartily Mrs. Rannveig Ødegaard, Norwegian Plant Protection Institute, for typing and correcting these manuscripts dealing with East African rust fungi.

Aecidium aspiliae n.sp. (Fig. 1)

Pycnia epiphylla in maculis flavis, typus 4. Aecia hypophylla, in gregibus parvis aggregata, peridio albo, lacerato, revoluto. Cellulae peridii rhomboideae, 30 x 20 µm, pariete interno verrucoso, 3 µm crasso, pariete externo striato, 9 µm crasso. Aeciosporae oblongae vel angulares, 16-20 x 13-15 µm, pariete 0.5 µm crasso, hyalino, verruculoso, saepe particulas paucas parvas lucentes continentes, poris obscuris.
Holotype: H.B. Gjærum 71 (MHU), 09.09.1970, Uganda, W. Mengo, Busiro Co., Zika Forest, 1160 m, on *Aspilia pluriseta* Schweinf. (Asteraceae). Isotype in NPPI.

Several rust species are described on the genus *Aspilia*, but the only one having aecia is *Puccinia fragilispora* Dale, described from Trinidad. According to the diagnosis (Dale 1955) it has much larger peridial cells and aeciospores, 30-70 x 20-41 and 30-48 x 20-27 µm, respectively.

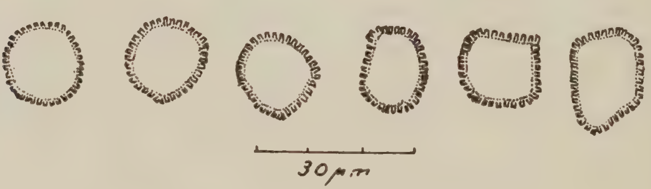


Fig. 1. *Aecidium aspiliae* n.sp.
Aeciospores from type.

Aecidium cynanchi Cumm., Bull. Torrey Bot. Club 68: 48, 1941.
On *Cynanchum* cf. *altiscandens* K. Schum. (Asclepiadaceae) Kenya. Central Prov., Suam Forest Station, 2100 m, 23.-24.01.1973, L. Ryvarden (9276, O), I.

No pycnia seen. Aecia hypophyllous in yellow leaf spots. Peridium white, tubeformed, slightly lacerate and revolute at the top. Aeciospores irregularly angular, 15-21 x 13-18 µm, wall 1 µm thick, hyaline, verruculose.

This species which is new to the rust flora of Kenya, was described from Sierra Leone on *C. mannii* N.E. Br. , and it is later reported on the same host from Ghana. *C. altiscandens* is a new host for this rust.

Aecidium dichrocephalae P. Henn., Monsunia 1: 4, 1899.

On *Dichrocephala integrifolia* O. Kuntze (Asteraceae) Bugisu Distr., N. Bugisu Co., Bumasifwa, above the school, 1300 m, Gj. (404); Ankole Distr., Bunyaruguru Co., Kalinzu Forest, 1400 m, Gj. (140); Kigezi Distr., Bufumbira Co., on track to Gahinga, just above the border of cultivated land, 2300 m, Gj. (241).

Pycnia epiphyllous, yellow brown. Aecia hypophyllous, in great clusters. Peridium white, revolute, lacerate. Aeciospores ellipsoid, ovoid or irregular, 25-33 x 15-20 µm, wall 1 µm thick, at apex thickened up to 8 µm, hyaline and densely verrucose.

This aecial stage has been reported by Wakefield & Hansford (1949) on *D. latifolia* DC. from Kigezi and on *D.* sp. from Bugisu, and by Ebbels (1972, as *A. matapense* Cumm., IMI 155315) from Kigezi. Outside Africa it is known on *D.* spp. from Java, Assam, Taiwan, and New Guinea.

Aecidium dubiosum H. & P. Syd., Hedwigia 40: (1), 1901.

On *Senecio* sp. (Asteraceae)
Bugisu Distr., N. Bugisu Co., Mt. Elgon, at Sasa River on track to Sasa Hut, 2850 m, Gj. (386), 0 + I.

Pycnia epiphyllous, yellow-brown. Aecia hypophyllous in great clusters. Peridium white, revolute, lacerate. Aeciospores ellipsoid, ovoid or irregular, 24-33 x 15-21 µm, wall 1 µm thick, at apex thickened up to 7 µm, hyaline, densely verruculose, pores obscure.

A. dubiosum, a new rust species in Uganda, has been reported on several *Senecio* spp. in Africa, esp. from S. Africa, but it is also known in Malawi. Outside Africa it has been found in Portugal.

Aecidium echuyaënse n.sp. (Fig. 2)

Pycnia epiphylla, diam 130 um, typus 4. Aecia hypophylla, in gregibus parvis aggregata, peridio albo, longo. Cellulae peridii usque 40 µm longa, pariete 4 µm crasso, pariete interno striato, pariete externo verruculoso. Aeciosporae ellipsoideae vel subgloboideae, 23-33 x 18-27 µm, pariete 1 µm crasso, hyalino, verruculoso, poris obscuris.

Holotype: H.B. Gjærum 230a (MHU) 01.10.1970, Uganda, Kigezi Distr., Rubanda Co., Echuya Forest Reserve, Mile 34-35 on the Kabale-Kisoro road, 2100 m, on *Helichrysum foetidum* (L.) Cass. s. lat. (Asteraceae). Isotype in NPPI.

In the literature available to me three aecial stages are mentioned on *Helichrysum*, two of which are described with apurtenant telial stages, viz. *Puccinia macowanii* Wint. and *P. pinarii* Pole Evans. Doidge (1926) when describing *Aecidium helichrysi* indicated that it might belong to *P. kalchbrenneri* De Toni. The latter has thicker spore wall, 2.5-3 µm and *P. macowanii* has thicker peridial cell walls and more globose spores than described for the new species. The aecial stage of *P. pinarii* might be that which is closest but the spores have a granular content which the spores of *A. echuyaënsis* do not have.

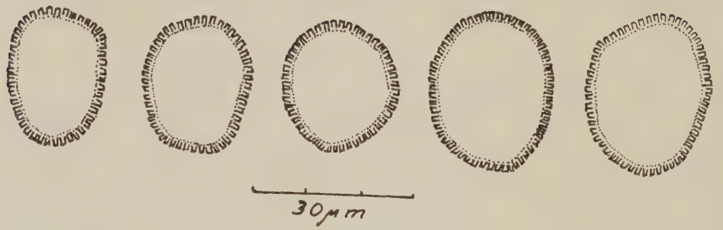


Fig. 2. *Aecidium echuyaënsis* n.sp.
Aeciospores from type.

Aecidium flavidum Berk. & Br., J. Linn. Soc. London 14: 95, 1873.
On *Pavetta schumanniana* K. Schum. (Rubiaceae)
Tanzania. Iringa Distr., Ruaha National Park, at Magangwe Air Strip, 1340 m, 11.03.1972, A. Bjørnstad (1540, O), I.

Pycnia epiphylla. Aecia hypophyllous, in groups on yellow-brown leaf spots. Peridium brownish (old), revolute. Spores subgloboid or angular, 23-32 x 20-23 μm, wall 1-1.5 μm thick, verruculose and with refracting granules.

A. flavidum, widespread in Tropical Africa and Asia, was reported from Uganda by Wakefield (1920) and Wakefield & Hansford (1949) on *Pavetta* sp. from Kivuvu in Kyagwe. The host is new to the fungus in Uganda, but has been reported from Zambia.

Aecidium gynurae Petch, Annal. R. Bot. Gdns Peradeniya 5: 244, 1912.
Syn. *A. formosanum* Syd. Annls mycol. 11: 56, 1913; *A. emiliae* Petch. Annal. R. Bot. Gdns Peradeniya 6: 212, 1917; *A. gynurae* March. & Stayert. Bull. Soc. r. Bot. Belg. 61, sér. 2: 165, 1919; *A. crassochephali* Wakef. & Hansf. Proc. Linn. Soc. Lond., Sess. 161. 1948-49, Pt. 2: 189, 1949; *A. gynurae-cernuae* Vien.-Bourg., Bull. Soc. Mycol. Fr. 70: 411, 1955.
On *Crassocephalum crepidioides* (Benth.) DC. (syn. *Gynura crepidioides* Benth.) (Asteraceae)
W. Mengo Distr., Kyadondo Co., Makerere Hill 1200 m, Taksdal & Gj. (Gj. 7); 16.11.1970, leg. A.C. Tallantire; Kabanyolo, 1200 m, Gj. (487); Mawakota Co., Mpanga Forest 1150 m, Gj. (177); Busiro Co., Kisibawo 1200 m, Gj. (189), Entebbe, 1150 m, Gj. (38); E. Mengo Distr., Kyagwe Co., near Bugombe on Kome Island, 1150 m, 27.10.1968, K.A. Lye; Teso Distr., Serere Co., Serere Research Station 1150 m, Gj. (431), 0 + I.

On C. rubens (Jacq.) S. Moore
Mubende Distr., Singo Co., Hoima 1500 m, Gj. (325); Bunyoro Distr., Buruli Co., Bunyoro Ranch near Masindi 27.12.1961, Turner (452), 0 + I.

Pycnia epiphyllous, type 4, rare. Aecia in dense clusters, mainly on the lower side of circular, yellow-brown leaf spots. Peridium short, revolute, white to yellowish. Aeciospores angularly globoid or ellipsoid, 16-19 x 14-16 µm, wall 1 µm thick, hyaline, verruculose and with some refracting granules.

To my knowledge pycnia have not been mentioned earlier, and they occur in most specimens examined.

This aecial stage is widespread in tropical Africa and in Asia east to the Philippines, Taiwan and the Ryukyus, and it is also reported from Queensland. The main host genus in Africa is Crassocephalum (incl. Gynura). In Asia Emilia is the main host genus, but Gynura and Senecio are also reported.

Viennot-Bourgin (1958) recognized three Aecidium species, A. gynurae Petch (syn. A. emiliae and A. formosanum), A. mariani-raciborskii Siem. and A. crassocephali (syn. A. gynurae March. & Stayert and A. gynurae-cernuae Vien.-Bourg.) while Bouriquet & Bassino (1965) placed them within A. crassocephali. After having studied the Ugandan material presented above and the types of A. gynurae Petch and A. crassocephali (Herb. K) as well as their diagnosis, I find it most convenient to treat them as one species. According to the diagnosis, the third species recognized by Viennot-Bourgin, viz. A. mariani-raciborskii, has larger spores than have the other species discussed. As the type specimen probably has been lost (T. Majewski in litt.) and the spore measurements thus cannot be verified, I find it better to keep it separate.

Wakefield & Hansford described A. crassocephali on C. crepidioides from Busoga. C. rubens is a new host for this rust in Uganda, but it has been reported as a host from Tanzania and Malawi.

Aecidium haplocarphae sp. nov. (Fig. 3)

Pycnia non visa. Aecia amphigena, pro maximam partem hypophylla, in maculis ferrugineis plus minusve rotundatis, diam 300-400 µm, aggregata, peridio lacerato, revoluto, juvenilio albo, demum pallide brunneo. Cellulae peridii rhombohydrales, imbricata, pariete externo 4 µm crasso, striato, pariete interno 2 µm crasso, grosso verruculoso. Aeciosporae globoideae, ovoideae vel polyhedroideae, 17-24 x 14-18 µm, pariete pallide brunneo, 1.5-2.5 µm crasso, dense verruculoso, saepe particulas paucas parvas lucentes continentibus, poris obscuris.
Holotype: H.B. Gjærum 412 (MHU), 24.10.1970, Uganda, Bugisu Distr., N. Bugisu Co., Mt. Elgon, between Sasa Hut and Jackson's Summit, 3800 m, on Haplocarpha rueppellii (Sch. Bip.) Beauv. (Asteraceae). Isotype in NPPI.

The host occurs at an altitude between 2750 and 4700 m in the mountains in Ethiopia, Kenya, Uganda and

Tanzania. At Mt. Elgon it was found up to 4300 m. So far no rust seems to be reported from this host. Nattrass (1961) reported a *Uredo* sp. on the closely related *H. schimperi* (Sch. Bip.) Beauv. from Kenya, but the specimen in CMI (IMI 45433) is recorded as a species of *Landtia*.

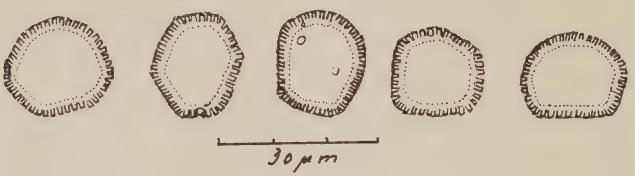


Fig. 3. *Aecidium haplocarphae* n.sp.
Aeciospores from type.

Aecidium macowanianum Thuem., Flora 58, 380, 1875.
On *Conyza* sp. (Asteraceae)
Kenya. Eastern Prov., Nyeri Distr., Mt. Kenya, S slope, Regati Forest Station, 2200-2300 m, 02.-03.02.1973, L. Ryvarden (9112, O), I.

Pycnia not seen. Aecia amphigenous, in dense clusters. Peridium white, revolute, lacerate. Aeciospores subgloboid or somewhat angular, 15-21 x 13-19 µm, wall 1 µm thick, in some spores thickened to 2,5 µm at apex, hyaline, verrucose.

This aecidial stage was reported by Wakefield & Hansford (1949) on *C. hochstetteri* Sch. Bip. ex A. Rich. from Ankole and on *C.* sp. from Kabale in Kigezi and from Kampala. On other *Conyza* spp. it has been reported from Kenya, Tanzania, Angola and S. Africa, and also from India.

Henderson (1972) compared *A. macowanianum* with *A. conyzae-pinnatilobatae* P. & H. Syd. The latter is said to be thickened at the apex, while the former has evenly thick-walled spores. In his material Henderson found that it showed "slight signs of irregular wall thickening so the two species may not be absolutely distinct". The Mt. Kenya specimen shows in some spores a slight wall thickening, but not as much as given in the diagnosis for *A. conyzae-pinnatilobatae* (in the diagnosis up to 5 µm).

Another species, *A. hoffmannii* P. & H. Syd., described on *Conyza limosa* O. Hoffm. from S. Africa has somewhat larger aeciospores with apex thickened up to 8 µm.

Aecidium plectranthi Barcl., J. Asiat. Soc. Beng. 59 (II): 104, 1890.

On *Plectranthus sylvestris* Gürke (Lamiaceae)
Kigezi Distr., Bufumbira Co., on the saddle between Muhavura and Gahinga, 3100 m, Gj. (256), I.

No pycnia seen. Aecia amphigenous, scattered or in small groups. Peridium white, tubeformed, slightly lacerate and revolute, cells 39-55 x 19-23 µm, walls 3-3.5 µm thick, outer wall striate, inner wall verrucose. Aeciospores obovoid to ellipsoid, 27-32 x 18-27 µm, wall 1.5 µm thick, hyaline, verrucose, pores obscure.

In addition to *E. plectranthi* two more species with aecia are described on *Plectranthus*, viz. *A. plectranthicola* Cumm. and *Puccinia plectranthi* Thuem. The former differs from *A. plectranthi* having aeciospores strongly thickened at the apex. The aecia of *P. plectranthi* were poorly described by Cooke (1882), only said to be hypophyllous with yellow spores. The specimen studied by me lacks pycnia and has amphigenous, mainly epiphyllous aecia. Spore contents pale yellowish. As there are no telia I prefer to place it with *A. plectranthi* (see also Doidge 1926).

A. plectranthi is new to the rust flora of Uganda. In Africa it is reported on *Pl. floribundus* N.E.Br. from Simbabwe and S. Africa, on *Pl*. sp. also from Tanzania. In Asia it is known from N.W. Himalaya, China, Japan and E. Siberia. *P. sylvestris* is a new host for this rust.

Aecidium pycnostachydis (Kalchbr.) Doidge, Bothalia 2: 178, 1927.
Syn. *Uredo pycnostachydis* Kalchbr., Grevillea 11: 25, 1882.
On *Pycnostachys meyeri* Gürke (Lamiaceae)
Kigezi Distr., Bufumbira Co., in the lower forest border on track to Gahinga, 2700 m, Gj. (244), I.

Pycnia not seen. Aecia amphigenous, scattered or in small groups on brown leaf spots, cupulate. Peridium white, revolute, lacerate. Spores angular to ellipsoid, 25-30 x 20-23 µm, wall 1.5 µm thick, verrucose with irregular warts.

This aecial stage, described from S. Africa, was reported by Wakefield (1920) and later by Wakefield & Hansford (1949) on *P. dawei* N.E. Br., from Mugomba in Kyagwe. It has also been recorded from Zimbabwe. *P. meyeri* is a new host for this rust.

Aecidium vernoniae-podocomae Doidge, Bothalia 2: 212, 1927.
On *Vernonia auriculifera* Hiern (Asteraceae)
W. Mengo Distr., Kyadondo Co., Namulonge and Kabanyolo, 1200 m, Gj. (82, 280), Busiro Co., Kisibawo, 1200 m, Gj. (190), Mawokota Co., Mpanga Forest, 1150 m, Gj. (174), all I.
Ethiopia. Shoa Distr., Wondo Gennet, 1800 m, Gj., I.

Aecia hypophyllous, yellow-brown, round, circular, scattered or a few loosely together. Peridium white, often broken. Aeciospores angular, 17-28 x 17-20 um, wall 1 µm thick, hyaline, densely verruculose, with very small refracting granules.

Wakefield & Hansford (1949) reported this aecial stage on Vernonia sp. from Kawanda in Kyadondo.

Endophyllum (?) striatosporum Wakef. in Wakefield & Hansford, Proc. Linn. Soc. Lond., Sess. 161, 1948-49, pl. 2: 162-198, 1949.
On Rhamnus prinoides L'Hérit. (Rhamnaceae)
Ethiopia. Shoa Distr., D. Yirgou 258 (IMI 116576), III.
On Rhamnus sp.
Tanzania. Arusha Prov., Mt. Meru, E slope, Meru Crater, 2000 m, 17.05.1970, Nils Lundqvist (6502, UPS).

Aecia densely clustered on leaves and hypertrophied twigs, peridium long, tubular, revoluted, white. Spore-masses yellowish. Aeciospores subgloboid to ellipsoid, angular 17-27 x 15-20 µm, wall 2.5-5 µm thick, hyaline, striate.

The rust was described on R. prinoides from Sabei in Uganda. It has later been reported as E. macowanii Pole-Evans on the same host from Tanzania (Henderson 1970) and Ethiopia (Stewart & Yirgou 1967). E. macowanii, also reported from Tanzania and other African countries from S. Africa to Sudan, has verruculose spores.

Wakefield pointed out that she had not seen the spore germination, but she placed the rust tentatively in the genus Endophyllum "because of its suggestive resemblance to E. MacOwani Pole Evans". To my knowledge nobody has studied germination.

Endophyllum superficiale (Karst. & Roum.) Stev. & Mandiola, Philipp. Agric. 20: 13, 1931.
Syn. Aecidium clerodendri P. Henn., Bot. Jb. 15: 6, 1892.
On Clerodendron cordifolium (Hochst.) A. Rich. (Verbenaceae)
Acholi Distr., Lamwo Co., 3 km SW of Lotuturi, 1600 m, 17.02.1969, K.A. Lye & R.N. Lester (2040).

Sori round or irregular, thickened, bullate. Spores oblong or rectangular 23-28 x 20-23 µm, wall 1 µm thick, verrucose, hyaline.

The rust is new to Uganda, but it has been found in Malawi and Zambia. In Asia it has been found from India to China and Japan on several Asiatic Clerodendron spp. and also on Sterculia in Vietnam. C. cordifolium is a new host for the rust.

Hemileia canthii Berk. & Br., J. Linn. Soc. Bot. Lond. 14: 93, 1875.
On Canthium quenzii Sond. (Rubiaceae)
Kenya. Kwale Distr., Shimba Forest, near Pengo Hill, 09.01.1970, A.B. Katende & K.A. Lye (4810), II.

Uredinia hypophyllous in small tufts, yellow when fresh, when dry white. Urediniospores irregular, angular, ellipsoid, often flattened at one side, depending on the orientation of the spore, 30-34 x 20-25 µm, wall 1 µm thick, verrucose, but partly smooth, hyaline.

H. canthii is new to the rust flora of Uganda, and C. quenzii is a new host for it. In Africa it has been reported from S. Africa, Ghana, Angola and Tanzania on Canthium spp. and also on Plectronia sp. In Asia it is found in Pakistan, India, Sri Lanka and the Philippines on the same host genera as in Africa, in Pakistan also on Holarrhena antidysenterica Wall.

Hemileia holstii P. & H. Syd., Monogr. Ured. 3: 213, 1915.
On Psychotria kirkii Hiern var. hirtella (Oliv.) Verdc. (Rubiaceae)
Masaka Distr., Bukoto Co., near Bugonzi, 1160 m. 30.05.1971, K.A. Lye (M 56 B), II.

Uredinia amphigenous, mainly hypophyllous, small, scattered or confluent, pulverulent. Spores obovoid to globoid, flattened at one side, depended on orientation, 22-27 x 16-20 µm, wall 1 µm thick, hyaline, roughly verrucose, but partly nearly smooth.

This rust has been found in Kenya, Tanzania, Zambia, Malawi and Uganda, in the latter country on P. nigropunctata and P. sp. (Wakefield & Hansford 1949). P. kirkii var. hirtella is a new host for this rust.

Hemileia scholzii H. & P. Syd., Bot. Jb. 45: 260, 1910.
Syn. Uredo scholzii P. Henn., Bot. Jb. 33: 34, 1902.
On Clerodendron rotundifolium Oliv. (Verbenaceae)
Kigezi Distr., Rubanda Co., Mile 26 on the Kabale-Kisoro road, 2100 m, Gj. (210), II; Bunyoro Distr., Bujenje Co., Itutwe borehole, 1050 m, Gj. (335), II.

Uredinia hypophyllous, in dense groups, orange-yellow. Urediniospores 23-29 x 20-23 µm, bilaterally ovate, lower part smooth or nearly so, wall hyaline, 1.5-2(-2.5) µm thick, echinulate.

Wakefield & Hansford (1949) reported this rust C. johnstonii Oliv., C. capitatum Schum. & Thonn. and C. sp. from several localities from the Kampala-Entebbe area to Kigezi. It is widespread in Africa from Sudan to S. Africa, and also known in Mauritius and Samoa.

C. rotundifolium is a new host for the rust.

Hemileia vastatrix Berk. & Br., Gdns Chron. 1869: 1157.
On Coffea arabica L. (Rubiaceae)
W. Mengo Distr., Kyadondo Co., Kawanda, 1180 m, Gj. (491), II; Bugisu Distr., N. Bugisu Co., above Bumasobo school, 1500 m, Gj. (339), II; Toro Distr., Busongora Co., near Kyakikere on Zaire border, 1400 m, 21.04.1970, K.A. Lye (M16), II.
On C. canephora Pierre ex Froehner
W. Mengo Distr., Kyadondo Co., Makerere, 1200 m, Gj.

(456), 03.09.1970, C. Lwanga, II, Kabanyolo, 1200 m, Gj. (286), II, Mawokota Co., Mpanga Forest, 1150 m, Gj. (176), II.

Uredinia hypophyllous, yellow-orange. Urediniospores 21-38 x 15-23 µm, wall nearly hyaline, roughly echinulate and thicker on the upper (convex) side than on the lower side which is nearly smooth.

According to Wakefield & Hansford (1949) this rust is common throughout the country. They also report C. liberica Hiern and C. excelsa Cheval. as hosts. Henderson (1970) reported it on Gardenia jovis-tonantis Hiern from Kasambya. The coffee rust is widespread in Africa, in tropical Asia and Oceania, and also in S. and C. America from Argentina to Mexico.

Hemileia woodii Kalchbr. & Cooke, Grevillea 9: 22, 1880.
On Vangueria acutiloba Robyns (Rubiaceae)
W. Mengo Distr., Busiro Co., Kisibawo, near Mile 13 on the Kampala-Hoima road, 1200 m, Gj. (186), II; Teso Distr., Serere Co., Serere Research Station, 1150 m, Gj. (449), II.

Uredinia hypophyllous, sori small, in groups on greyish brown leaf spots. Urediniospores bilaterally ovoid, 27-34 x 14-20 µm, depending on the orientation of the spore, wall 1.5 µm thick, hyaline, echinulate except for the concave side which is smooth.

This rust species, new to Uganda, is widespread from Ethiopia through Kenya, Tanzania, Zambia and Zimbabwe to S. Africa, and it is also known in India. The main host genus is Vangueria. V. acutilobia has been reported from Tanzania.

Phakopsora vernoniae Jørst., Ark. Bot., Ser. 2, Bd. 17: 567, 1956.
On Vernonia amygdalina Del. (Asteraceae)
W. Mengo Distr., Kyadondo Co., Kabanyolo, 1200 m, Gj. (278), II.
On Vernonia campanea S. Moore
W. Mengo Distr., Mawokota Co., Mpanga Forest, 1150 m, Gj. (179), II.
On Vernonia juglandis Oliv. & Hiern
Kenya. Central Prov., Mt. Elgon, Suam Forest Station, 2100 m, 23.-24.01.1973, L. Ryvarden (9268, O), II+III.

Uredinia hypophyllous in brown leaf spots, scattered or in small groups, covered by epidermis which later crack, pale cinnamon-brown. Paraphyses cylindrical, curved or bent, rarely slightly capitate, wall thin, sometimes slightly thickened near apex. Urediniospores ellipsoid or obovoid, 20-34 x 17-23 µm, wall 1-1.5 µm thick, hyaline, echinulate. Telia hypophyllous, nearly black, crustlike. Teliospores in 3-4 layers, ellipsoid, 23-30 x 14-18 µm, wall 1 µm thick, brown.

This rust, which is new to Kenya and Uganda, was described on Vernonia sp. from Madagascar. The three hosts are new to the rust.

Physopella nyasalandica Cumm., Bull. Torrey Bot. Club 87: 37, 1960.
On Helichrysum gerberifolium Sch. Bip. (Asteraceae)
Masaka Distr., Kalungu Co., near Kasasa N of Mukoko, 1180 m, 05.06.1971, K.A. Lye (M 108), II.

Uredinia hypophyllous, in small groups, surrounded by curved paraphyses with a hyaline wall, slightly thickened at apex. Urediniospores ellipsoid to obovoid, 21-27 x 18-22 µm, wall pale yellowish, 1 µm thick, echinulate, pores obscure.

The rust is new to Uganda, previously known on H. petersii Oliv. & Hiern from Malawi.

Physopella wiehei (Cumm.) Cumm. & Ramachar, Mycologia 50: 743, 1958.
Syn. Angiopsora wiehei Cumm., Bull., Torrey Bot. Club 79: 213, 1952.
On Erlangea cordifolia (Benth.) S. Moore (Asteraceae)
W. Mengo Distr., Kyadondo Co., Kazi, 1160 m, Gj. (51), II; Busiro Co., Zika forest, 1160 m, Gj. (70), II.
On cf. Erlangea fusca S. Moore
Ethiopia. Shoa Prov., Wondo Gennet, 1800 m, 27.11.1970, Gj., II.

Uredosori hypophyllous, surrounded by more or less incurved hyaline paraphyses, upper wall 2-3 µm thick, near apex thickened to 8 µm lower wall 1-1.5 µm thick. Urediniospores ellipsoid or obovoid, rarely subgloboid, 19-28 x 16-22 µm, wall hyaline, 1-1.5 µm thick, densely echinulate, pores not visible.

Apart from the type locality, Cummins (1952) pointed out that the urediniospores described by Wakefield & Hansford (1949) as belonging to Puccinia erlangeae Grove on E. tomentosa from Kampala, belongs to Ph. wiehei.

E. cordifolia is a new host for this rust in Uganda, but it has previously been reported from Rwanda (Majewski & Nowak 1982). E. fusca is a new host for the rust which is new to the flora of Ethiopia.

Puccinia aecidiiformis Thuem., Flora 58: 378, 1875.
On Microglossa pyrifolia (Lam.) O. Kuntze (Asteraceae)
Mubende Distr., Buwekula Co., Mile 124 on road Kampala-Fort Portal, 1500 m, Gj. (495), III.
Kenya. Eastern Prov., Nyeri Distr., Mt. Kenya, S slope, Regati Forest Station, 2200-2300 m, 02.-03.02.1973, L. Ryvarden (9118, O), III; N.E. Elgon, 2100 m, 27.10.1960, Lind, III; Mt. Elgon, E. slope above Tweedie's sawmill, 2650 m, 22.02.1948, O. Hedberg (85, UPS), III.

Telia hypophyllous, in small groups, compact, yellowish. Teliospores ellipsoid, constricted at septum, 58-74 x 22-33 µm, wall hyaline, smooth, 1-1.5 µm thick, at apex thickened to 4 µm. Pedicel hyaline, persistent.

Spores collapse when germinating.

This rust which is new to the flora of Uganda, is previously known from Kenya, Tanzania and S. Africa, in Tanzania on the same host. Other host genera are Nidorella and Senecio. It is similar to P. aurata H. & P. Syd., living on the same host, but the teliospores are somewhat shorter, being up to 60 µm long and not thickened at the apex.

Puccinia africana Cooke, Grevillea 8: 71, 1879.
On Spilanthes mauritiana (A. Rich.) DC. (Asteraceae)
W. Mengo Distr., Kyadondo Co., Makerere, 1200 m, 03.12.1968, K.A. Lye (288), Gj. (264), and Kabanyolo, 1200 m Gj. (492); Mawokota Co., Mpanga forest, 1150 m, Gj. (178); Bugisu Distr., C. Bugisu Co., near Busano, 1600-1700 m, 21.01.1969, K.A. Lye (1681), N. Bugisu Co., Bumasifwa, 1300 m, Gj. & P. Rwaburindore (407); Kigezi Distr., Rubanda Co., Kalinzu forest, 1400 m, Gj. (137), all with III only.
Kenya, Central Prov., Mt. Elgon, Suam Forest Station, 2100, 23.-24.01.1973, L. Ryvarden (9259), III.

Telia hypophyllous in necrotic, brown leaf spots, irregular, in groups, confluent or scattered, chestnut-brown, greyish when germinated. Teliospores obclavate or ellipsoid, constricted at septum, often falling apart, 37-54 x 13-18 µm, wall 1.5 µm thick, thickened upward, at apex up to 4.5 µm, yellow-brown in upper cell, going to nearly hyaline at the base, smooth. Upper pore apical, lower at septum, not visible in ungerminated spores. Pedicel hyaline, persistent, short.

P. africana is widespread in tropical and southern Africa, and also in Madagascar, on S. acmella Murr. Wakefield & Hansford (1949) reported it on S. acmella from several localities in Uganda. S. mauritiana is a new host in Uganda, but it has been reported from Kenya and S. Africa. Another host, in Tanzania, is Cineraria grandiflora Vatke.

Puccinia artemisiae-afrae sp.nov. (Fig. 4)

Telia hypophylla, plus minusve rotundata, in gregibus irregulares vel in striis aggregata, pulvinata, brunnea, post germinationem albo-grisea. Teliosporae clavatae vel ellipsoideae, ad septa constrictae, 55-90 x 16-27 µm, pariete laevo, pallide brunneo, 1.5-3 µm crasso, apice aut parum externus aut magis productus obtusissimusque, usque 14 µm crasso, poro superiore apicali, poro inferiore prope septum, in sporas nondum germinatas invisibilis, pedicello hyalino, usque 90 µm longo sed saepe breviore effracto.
Holotype: H.B. Gjærum 375 (MHU), 23.10.1970, Uganda, Bugisu Distr., N. Bugisu Co., Sasa Hut 3250 m, on Artemisia afra Jacq. ex Willd. (Asteraceae). Isotype in NPPI.

P. artemisiae-afrae which seems to be a leptosporic species, resembles in many characters some of the forms aggregated in the species P. cnici-oleracei Pers. ex Desm., but the teliospore size easily separates it from the latter species. Compared with P. artemisiae-sibiricae Jørst., described from Mongolia, it is separated by its larger and paler brown teliospores. The apex is not so thickened and more regularly attenuated as in P. artemisiae-sibiricae.

Artemisia afra occurs in the more elevated areas from Ethiopia to South Africa, at Mt. Elgon up to 4100 m altitude. From Natal, Transvaal and the Cape Province it has been reported as a host for P. tanaceti DC. (syn. P. absinthii (Hedw.f.) DC.).

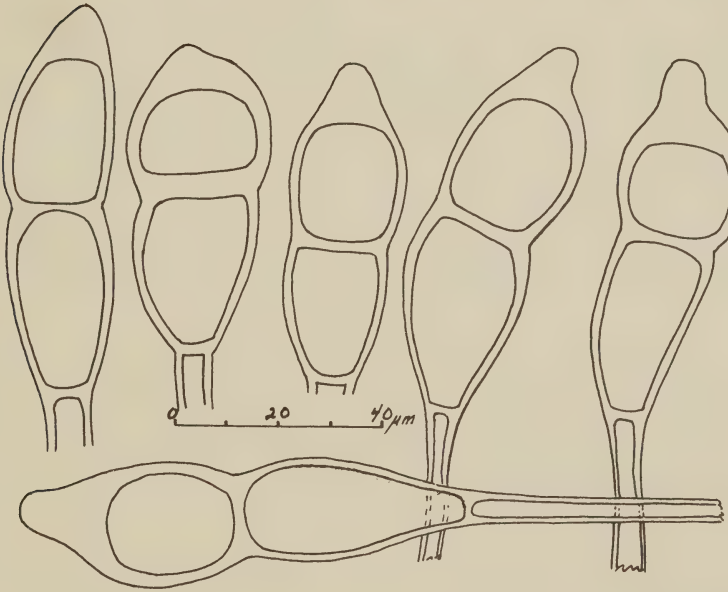


Fig. 4. Puccinia artemisiae-afrae n.sp.
Teliospores from type.

Puccinia bakoyana Pat. & Har., J. Bot. Paris 14: 237, 1900.
Syn. Aecidium mitracarpi H. & P. Syd., Annls mycol. 10: 79, 1912.
On Mitracarpus villosus (Sw.) DC. (Rubiaceae)
Teso Distr., Soroti Co., Arapai Research Station, 1100 m, Gj. (416), I.

Aecia in groups, mainly hypophyllous, peridia white. Aeciospores angularly subgloboid or ellipsoid, pale yellowish, 16-20 x 14-17 µm, wall 1 µm thick, verruculose and with refracting granules.

Mayor (1964) who made biometrical studies of the three rubiaceous rust species P. lateritia Berk. & Curt., P. borreriae P. & H. Syd. and P. bakoyana could not separate them morphologically. Therefore, he placed them all within P. lateritia, the first described one. Eboh (1977) found that aecia on M. scaber, corresponding to A. mitracarpi were displaced by telia matching those described for P. bakoyana. He pointed out that the two other species had longer spores, in P. borreriae also strongly thickened at apex. As aecia are not mentioned for the two other species, and the material studied by me consists only of aecia, I prefer to follow Eboh and place it within P. bakoyana.

Wakefield & Hansford (1949) reported it as A. mitracarpi from Serere in Teso. The rust is widespread in Tropical and South Africa on species of Borreria, Diodia, Mitracarpus and Spermacoce. M. villosus is a new host for the rust.

Puccinia becii Doidge, Bothalia 2: 200, 1926.
On Becium obovatum (E. Mey.) N.E. Br. (Lamiaceae)
E. Mengo Distr., Kyagwe Co., on the hills near Kimera, 1300 m, 11.09.1969, K.A. Lye, Rwaburindore & Faden (3844), I.

Aecia hypophyllous, in small, dense clusters. Peridium revolute, white. Aeciospores angular, 14-18 x 12-16 µm, wall 1 µm thick, hyaline, delicately verruculose, and with refracting granules.

This rust is new to the rust flora of Uganda, described on the same host from Transvaal in S. Africa and later reported from Malawi, and from there also on B. odontopetalum C.H. Wright.

Puccinia cephalandrae Thuem., Flora, p. 425, 1876.
Syn. Aecidium cephalandrae Cooke, Grevillea 13: 6, 1884.
On Zehneria scabra (L.f.) Sond. (Cucurbitaceae)
Mubende Distr., Singo Co., Mile 101 on the Kampala-Hoima road, 1400 m, Gj. (319), I + II + III.

Aecia hypophyllous, in small groups. Peridium white. Aeciospores subgloboid or obovoid, 21-25(-32) x 17-23 µm. Wall 1-1.5 µm thick, hyaline, verruculose, some spores with refracting granules. Uredinia hypophyllous, round or oblong, scattered or in small groups, cinnamon-brown. Urediniospores ellipsoid or subgloboid, 23-28 x 18-25 µm, wall 1 μm thick, cinnamon-brown, echinulate and with 2 equatorial pores. Telia in the uredinia, dark brown. Teliospores ovoid or ellipsoid, with a pointed apiculus, slightly constricted at septum, 37-47 x 27-33 μm, wall 3-4(-4.5) μm thick, brown, with ridges, best seen on dry spores, upper pore apical, lower pore at septum. Pedicel hyaline, deciduous.

The rust is new to the flora of Uganda, but it has been recorded on several host genera in S. Africa, and it is also known from Kenya, Zambia and Zimbabwe. *Z. scabra* is a new host for this rust.

The Indian species *P. cephalandrae-indicae* H. & P. Syd. differs from *P. cephalandrae* having urediniospores with scattered pores and smaller, verrucose teliospores.

Puccinia crassocephali n.sp. (Fig. 5)

Pycnia, aecia et uredinia non visa. Telia hypophylla, compacta, parva, rotundata vel irregularia, confluentia, flavescentia. Teliosporae obclavatae, rotundatae vel interdum ad apicem oblique attenuatae, ad septum leviter constrictae, 33-50 x 10-17 μm, pariete 1-1.5 μm crasso, ad apicem usque 6 μm incrassato, laevi, hyalino, poro superiore apicali, poro inferiore obscuro (? prope septum), pedicello hyalino, minus quam 10 μm longo.
Holotype: H.B. Gjærum 255 (MHU), 02.10.1970, Uganda, Kigezi distr., Bufumbira Co., at the saddle between Gahinga and Muhavura, 3100 m, on *Crassocephalum aframontanum* R.E. Fr. (Asteraceae). Isotype in NPPI.

To my knowledge no *Puccinia* has been described for the genus *Crassocephalum*. *Puccinia* species described for allied host genera do not fit the *P. crassocephali*. Nearest seems to be *P. schizocarphae* Jacks. & Holw., described from Guatemala and also reported from Colombia. However, a comparison with the type (herb. K) shows that this species has more yellow sori and teliospores less constricted at septum with a thicker apical wall than has the new species.

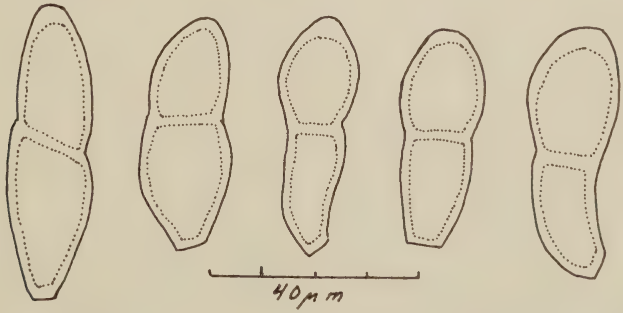


Fig. 5. *Puccinia crassocephali* n.sp.
Teliospores from type.

Puccinia desertorum H. & P. Syd., Bot. Jb. 45: 259-265, 1910.
On Evolvulus alsinoides (L.) L. (Convolvulaceae)
Kenya. Central Prov., Thika Distr., 5 km WSW of Thika, B. Hanis Farm, 1500 m, 24.01.1970, L. Ryvarden (5639, O), II; Coast Prov., Taita Distr., Tsavo National Park, East, 10 km ENE of Voi, Ndolola, 500 m, 08.01.1970, L. Ryvarden (5010, O), II.

Uredinia amphigenous, round to ellipsoid, sometimes coalescent, brown. Urediniospores globoid to ellipsoid, 25-29 x 22-26 µm, wall yellowish brown, distantly echinulate, 2.5-3 µm thick, with two equatorial pores covered with low, hyaline papillae.

The rust, described on the same host from Namibia and also reported from India, is new to the flora of Uganda. Jørstad (1956) pointed out that P. desertorum "does not appear to be very different" from P. lithospermi Ell. & Kellerm., mainly reported from the Americas, but also from the Philippines and India, often found on the host mentioned above.

A comparison of the type of P. desertorum with three American specimens of P. lithospermi (all specimens herb. S) showed that the teliospores of the latter were darker brown than those of the former. Whether this difference is significant or not can probably be decided only from study of more material from both continents, including also the type of P. lithospermi.

Puccinia difformis Kuntze in Kuntze & Schm., Myk. Hefte, 1: 71, 1817.
Syn. P. ambigua (Alb. & Schw.) Lagh. ex Bub., Sitz. ber. K. Böhm. Ges. Wiss., Math.-nat. Cl. 1898: 14, 1898.
On Galium spurium L. (syn. G. vaillantii DC.) (Rubiaceae)
Bugisu Distr., N. Bugisu Co., Mt. Elgon, bamboo forest above Sasa River on track to Sasa Hut, 3000 m, Gj. (382) I + III.

Aecia hypophyllous, cup-shaped and with revolute peridia. Aeciospores angular, oblong or globoid, 20-25(-30) x (13-)17-23 µm, wall 1 µm thick, hyaline, verruculose and with refracting granules. Telia in streaks on stems, on leaves hypophyllous, rounded. Teliospores cylindric to obclavate, slightly constricted at septum, 42-60 x 18-22 µm, wall 1-1.5 µm thick, thickened at apex to 11 µm, cinnamon-brown, brighter at apex and also in the lower part of the spore. Pedicel nearly hyaline, persistent.

Telial sori and teliospores are not as dark brown as they usually are, possibly due to juvenility.

This rust is widespread in Europe, Asia and North America. In Africa it is known from Kenya and Algeria, and also from the Canary Island and the Azores. The main host is G. aparine. The rust is new to Uganda, but the host is reported with the rust in Norway (Hylander et al. 1953, as G. vaillantii).

Puccinia dummeri Wakef. in Wakefield & Hansford, Proc. Linn. Soc. Lond., Sess. 161, 1948-49, Pt. 2: 178, 1949.
On *Echinops hoehnelii* Schweinf. (Asteraceae)
Bugisu Distr., N. Bugisu Co., near Sasa River on track to Sasa Hut, 2900 m, Gj. (385), II.

Uredinia hypophyllous, scattered, irregular, brown. Urediniospores subgloboid, sometimes globoid or obovoid, 32-37 x 31-37 µm, wall 1-1.5 µm thick, cinnamon-brown, echinulate and with 3 equatorial pores.

This rust seems not to be known outside Uganda where Lumbwa in Kyagwe is type locality. Type host is *E. amplexicaulis* Oliv. It is also reported on *E. gigantei* A. Rich. and *E*. sp. *E. hoehnelii* is a new host for the rust species.

P. dummeri is closely related to *P. pulvinata* Rabenh. and *P. echinopis* DC. (Wakefield & Hansford op. cit.). *P. pulvinata* differs from *P. dummeri* in having urediniospores with 2 slightly superequatorial pores. *P. echinopis* (=*P. calcitrapae* DC.) has 3 equatorial pores. However, spore sizes for *P. calcitrapae* given in literature vary, but they are mostly smaller than found in my material. Teliospore length is also shorter than given in the diagnosis for *P. dummeri*.

Puccinia erlangeae Grove, Bull. Misc. Inf. R. Bot. Gdns Kew No. 10: 270, 1916.
On *Erlangea cordifolia* (Benth.) S. Moore (Asteraceae)
W. Mengo Distr., Busiro Co., Zika forest, 1160 m, Gj. (70), II; Bugisu Distr., N. Bugisu Co., on track to Sasa Hut, below Bulambuli Escarpment, 2000 m, Gj. (409), III.
On *E*. cf. *fusca*
Bugisu Distr., N. Bugisu Co., Sasa Hut, 3250 m, Gj. (372), III.

Uredinia hypophyllous, brown. Urediniospores subgloboid, ellipsoid or obovoid, 24-32 x 21-24 µm, wall 2-2.5 µm thick, densely echinulate and with 2 distinct, equatorial pores. Telia amphigenous, mostly hypophyllous, oval or oblong on veins, brown, pulverulent. Teliospores 31-41 x 24-30 µm, broadly ellipsoid, mostly rounded at both ends, slightly constricted at septum, wall (1-)1.5-2(-2.5) µm, pale brown, upper pore apical, lower near the hyaline pedicel.

The teliospores on *E. cordifolia* are slightly shorter than are those on *E. fusca* and with a thicker wall, but the form, colour and echinulation are similar.

Wakefield & Hansford (1949) have previously reported this rust on *E. tomentosa* S. Moore from Bufundi in Kigezi and from Kampala. The urediniospores described from the specimen collected at Kampala, Cummins (1952) pointed out as belonging to *Angiopsora wiehei* Cumm. (= *Physopella wiehei* (Cumm.) Cumm. & Ramachar). The description of the urediniospores given by Henderson (1970) from Tanzania matches well with the urediniospores in the present material.

E. cordifolia is a new host record for this rust.

Puccinia guizotiae Cumm., Bull. Torrey Bot. Club 79: 221, 1952.
On Guizotia scabra (Vis.) Chiov. (Asteraceae)
Teso Distr., Serere Co., Serere Research Station, 1150 m, Gj. (435), III; Bunyoro Distr., Bugahya Co., Hoima, 1500 m, Gj. (331), III.

Telia hypophyllous, in dense clusters, compact, cinnamon-brown. Teliospores oblong-ellipsoid or obclavate, constricted at septum, 41-57 x 13-21 µm, wall 1-1.5 µm thick, at apex thickened to 6 µm, yellowish to pale brown, smooth, upper pore apical, the lower near septum, obscure in ungerminated spores. Pedicel hyaline to pale yellowish. One-celled spores occur.

The rust was described on G. scabra from Semuto Road in E. Mengo. Later it was reported on the same host from Lake Mulehe in Kigezi by Ebbels (1972), and on which it is also known from Kenya and Sudan. From Ethiopia it is reported on G. abyssinica (L.f.) Cass. and G. schultzii Hochst.

Puccinia hansfordiana Cumm., Bull. Torrey Bot. Club 70: 523, 1943.
On Senecio trichopterygius Muschl. (Asteraceae)
Kigezi Distr., Rubanda Co., Mile 26 on the Kabale-Kisoro road, 2100 m, Gj. (207), II; Rubanda Co., Echuya Forest, Mile 34-35 on the Kabale-Kisoro road, 2100 m, Gj. (228), II, Bufumbira Co., on track to Gahinga, below Forest Reserve Border, 2500 m, and at the saddle between Muhavura and Gahinga, 3100 m, Gj. (245, 254), II.

Uredinia mainly hypophyllous, round or oval in face view, scattered or in groups, brown. Urediniospores ellipsoid, obovoid or subgloboid, 27-37 x 23-30 µm, wall 1.5-2 µm thick, dark cinnemon-brown, echinulate, with 3 mainly equatorial pores.

This rust species was described on S. denticulatus Engl. from Kachwekano Farm in Kigezi. Wakefield & Hansford (1949) reported the same specimen.

S. trichopterygius is a new host for the rust.

Puccinia hedbergii L. Holm, Svensk bot. Tidskr. 67: 253, 1973.
On Senecio erici-rosenii R. & Th. Fries (Asteraceae)
Kigezi Distr., Bufumbira Co., Mt. Muhavura, W slopes, 3400 m, 03.10.1948, O. Hedberg (20566, UPS), III.

Telia amphigenous, irregular, scattered, pulverulent, cinnamon-brown. Teliospores ellipsoid or obclavate, slightly attenuate at apex, constricted at septum, (33-)40-57 x (15-)17-23 µm, wall 1-2 µm, at apex thickened to 3 µm, pale cinnamon-brown, smooth, pores obscure. Pedicel hyaline, long, persistent.

This rust was described on Senecio meruensis Cotton & Blakelock from Mt. Meru in Tanzania. It is new to the rust flora of Uganda and S. erici-rosenii is a new host for the rust. Both hosts belong to Dendrosenecio. In the Uganda specimen some spores are longer than in the diagnosis (38-48 x 20-25 µm).

Puccinia holosericea Cooke, Grevillea 10: 126, 1882.
On Ipomoea hederifolia L. (Convolvulaceae)
W. Mengo Distr., Busiro Co., Entebbe, near the Botanic Garden, 1150 m, Gj. (18), III; Bunyoro Distr., Bujenje Co., Nyabisabu near Nyabyeya, 1100 m, Gj. (352), III.
On Ipomoea involucrata Beauv.
Kigezi Distr., Rubanda Co., Nyamabala 2100 m, Gj. (226), III.
On Ipomoea wightii (Wall.) Choysy
Ankole Distr., Bunyaruguru Co., Kalinzu forest, 1400 m, Gj. (147), III.
On Ipomoea sp.
Kenya. Eastern Prov., Nyeri Distr., Mt. Kenya, S slope, Regati Forest Station, 2200 - 2300 m, 2.-3.2.1973, L. Ryvarden (9109, O), III.

Telia hypophyllous in necrotic spots, arranged in a circle around a central sorus, compact, cinnamon-brown to chestnut-brown. Teliospores oblong, ellipsoid or obclavate, slightly constricted at septum, rounded at apex, rarely attenuate or truncate, 33-54 x 15-20(-23) µm, wall 1.5-2 µm thick, at apex thickened to 8 µm, smooth, pale cinnamon-brown. Pedicel hyaline to pale cinnamon-brown, persistent. One-celled spores occur.

Wakefield & Hansford (1949) reported this rust on Convolvulaceae (in the register is said Ipomoea) from several places in Uganda. In Africa it is reported from several I. spp. including I. wightii. I. hederifolia and I. involucrata are new hosts for the rust which also occurs on Lepistemon owariense Hall.

Puccinia hoslundiae H. & P. Syd. emend. Vien.-Bourg., Uredineana 4: 175, 1953.
Syn. P. hoslundiae H. & P. Syd. in Deutsch. Zentr. Afrika Exped. 1907-8, 2: 97, 1914; P. hoslundiae Grove, Bull. Misc. Inf. R. Bot. Gdns Kew No. 10: 270, 1916.
On Hoslundia opposita Vahl (Lamiaceae)
Teso Distr., Serere Co., Serere Research Station 1150 m, Gj. (439/70) II + III.

Uredinia amphigenous, rounded, scattered or in groups. Urediniospores obovoid to subgloboid, 24-28 x 18-24 µm, wall yellowish brown (1.5-)2-2.5 µm thick, echinulate, with 2 equatorial pores, often obscure. Telia hypophyllous, rounded, dark brown. Teliospores ellipsoid, 28-43 x 22-24 µm, wall 3-3.5 µm thick, at apex thickened to 6 µm, finely verrucose. Pedicel hyaline, collapsing, in some spores as long as the spore, but mostly broken shorter.

Wakefield & Hansford (1949) who described the aecial stage of this rust, reported it from W. Mengo and Kigezi Districts. It is known on the same host in Sudan, Ghana and Ivory Coast. Type host is H. verticillata Vahl., described from Rwanda.

Puccinia isoglossae Doidge, Bothalia 2: 202, 1926.
On Hypoëstes verticillaris (L.f.) Soland ex Roem. & Schult. (Acanthaceae)
Karamoja Distr., Mt. Moroto, 2700-3100 m, 26.12.1960, E. Long Braun (60), III.

Telia hypophyllous, rarely epiphyllous, compact, in very dense groups, dark cinnamon-brown. Teliospores fusiform or cylindrical, slightly constricted at septum, 32-42 x 10-13(-16) µm, wall 1 µm thick, at apex thickened to 4 µm, hyaline, smooth. Pedicel hyaline, persistent.

P. isoglossae has been found scattered over Africa from Kenya and Sudan to S. Africa on H. verticillaris (originally described on Isoglossa ovata Nees and I. woodi C.B.Cl., but hosts wrongly identified - cf. Doidge 1948). It was described on H. cunninghamiana Benth. & Hook. from Taiwan as P. hypoëstis Sawada in 1943, but not validly published (cf. Laundon 1963).

Puccinia kalchbrenneri de Toni, Syll. Fung. 7: 645, 1888, var. kalchbrenneri.
On Helichrysum globosum Sch. Bip. (Asteraceae)
Ankole Distr., Bunyaruguru Co. Kalinzu Forest, near the sawmill, 1400 m, Gj. (144), II; Kigezi Distr., Rubanda Co., Lake Bunyonyi, Sharp's Island, 1800 m, Gj. (233), II, Rubanda Co., Mile 28 and Mile 34-35 on the Kabale-Kisoro road, 2100 m, Gj. (202 and 229), II, Kabale, 1800 m, Gj. (217), II + III, Kinkizi Co., Bwindi, Gj. (233), II + III.

Uredinia hypophyllous on lower side of yellow-brown spots, scattered or in small groups. Urediniospores obovoid to subglobose, 24-30 x 19-22 µm, wall 1 µm thick, pale yellowish, densely echinulate, pores obscure. Telia hypophyllous, dark brown. Teliospores ellipsoid or clavate, constricted at septum, 53-62 x 23-27 µm, wall yellow-brown, at apex nearly hyaline, 2 µm thick, at apex thickened up to 10 um, pedicel short, deciduous.

Wakefield & Hansford (1949) reported this on H. globosum, H. nudiflorum DC., H. undatum Less. and H. spp. from many localities between Mt. Elgon and Kigezi. This rust is also reported from Ethiopia, Malawi, S. Africa and India.

The var. valida Doidge, described from Transvaal has longer spores, up to 80 um, and with apex thickened up to 13 um.

Puccinia lantanae W.G. Farlow, Proc. Amer. Acad. Arts Sci. 18: 83, 1883. (Fig. 6)
On Barleria sp. near grantii Oliv. (Acanthaceae)
Kenya. Eastern Prov., Nyeri Distr., Mt. Kenia, S slope, Regati Forest Station, 2200-2300 m, 02.-03.02.1973, L. Ryvarden (9119, O).

Telia hypophyllous, small, round, often in dense groups, compact, brown. Teliospores light brown, two-celled spores ellipsoid or clavate, slightly constricted at septum, mostly rounded at the ends, but sometimes attenuate at apex or tapering to the pedicel, 27-40 x 15-21 µm, wall 1.5 µm thick, thickened to 8 µm at apex, smooth. One-celled spores common, ellipsoid, light brown, 27-30 x 15-21 µm. Pedicel hyaline.

P. lantanae was originally described on species of Lantana from the Americas. Laundon (1963) found that several other rusts described on hosts belonging to Acanthaceae showed the same feature and made them synonymous with P. lantanae, and indicated that P. heterospora might also be included. In Africa the rust is reported on Lantana amara from Ivory Coast and Ghana, and on L. sp. from Ethiopia. Barleria is a new host genus for this rust. Another African rust on this genus is Aecidium barleriae Doidge.

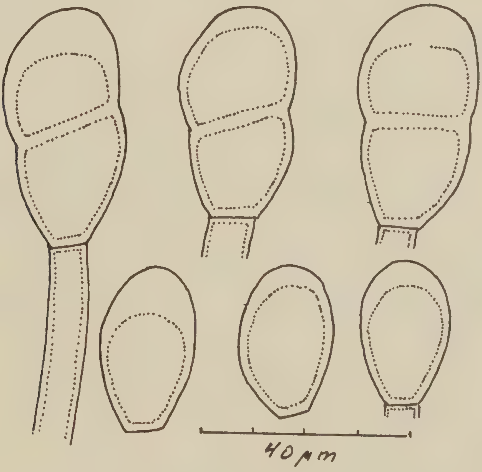


Fig. 6. Puccinia lantanae
Teliospores (from Ryvarden 9119, O)

Puccinia lateritia Berk. & Curt., J. Acad. Nat. Sci. Philad., New Ser. 2: 281, 1853.
On Spermacoce ocymoides Burm. f. (syn. Borreria ocymoides (Burm. f.) DC.) (Rubiaceae)
Bunyoro Distr., Bujenje Co., Budongo Forest, 1050 m, Gj. (350), III.
On Spermacoce princeae (K. Schum.) Verdc. (syn. Borreria princeae K. Schum.)
W. Mengo Distr., Mawokota Co., Mpanga Forest, 1150 m, Gj. (175), III; Bunyoro Distr., Bugahya Co., Hoima, 1500 m, Gj. (327), III.
On Spermacoce pusilla Wall. (syn. Borreria pusilla (Wall.) DC.)
E. Mengo Distr., Buruli Co., Mile 125 from Kampala on the Masindi road, 1250 m, Gj. (356), III, Mubende Distr., Singo Co., Mile 112 from Kampala on the Hoima road, 1000 m, Gj. (322a), III.
On Spermacoce ruelliae DC. (syn. Borreria ruelliae (DC.) H. Thoms)
E. Mengo Distr., Bulemezi Co., Nandere, 1200 m, 24.6.1960, Katete, III.

Telia hypophyllous on brown, nectrotic leaf spots. Sori rounded to oval, often confluent, compact, brown, becomming whitish when the spores germinate. Teliospores wide ellipsoid or obovoid, not constricted at septum, 27-37 x 15-24 μm, wall 2.5-3 μm thick, at apex thickened up to 7 μm, smooth, hyaline to pale cinnamon-brown, rarely cinnamon-brown. Upper pore apical, the lower near septum. Pedicel persistent, hyaline, sometimes obliqually attached to the spore. One-celled spores occur.

Wakefield & Hansford (1949) reported P. lateritiae on S. ruelliae (as B. ruelliae), S. senensis (Klotzsch) Hiern (as B. sinensis K. Schum.) and on Borreria sp. from several localities in Uganda. It is known from many countries in Africa, and also from India. Other host genera are Dioidia and Octodon. S. princeae seems to be a new host for the rust.

Puccinia leonotidicola P. Henn. in Baum, Bot. Ergebn. Kunene-Zambesi Exp. p. 157, 1903.
On Leonotis nepetifolia (L.) Ait.f. (Lamiaceae)
W. Mengo Distr., Kyadondo Co., Kampala, Makerere Hill, 1200 m, 28.09.1970, H.K. Taligoola, II, Gj. (266), II, Kabanyolo, 1200 m, Gj. (281), II, Mawokota Co., Nakysanja (Kawanda), 1180 m, 08.11.1970, J. Mukiibi, II, Teso Distr., Serere Co., Serere Research Station, 1150 m, Gj. (429), II.
Kenya. Eastern Prov., Nyeri Distr., Mt. Kenya, S. slope, Regati Forest Station, 2200-2300 m, 02.-03.02.1973, L. Ryvarden (9114, O), II.
On Leonotis sp.
Tanzania. Moshi Distr., Mt. Kilimanjaro Reg., between Lemosho and Shira Plateau, 2900 m, 21.01.1970, K.A. Lye, II.

Uredinia amphigenous, irregular, scattered, often covering the lower side, brown. Urediniospores subgloboid to globoid, rarely ellipsoid or obovoid, 23-30 x 22-28 µm, wall 1 µm thick, cinnamon-brown, echinulate and with (3-) 4-5 scattered pores.

The rust is widespread in warmer areas in the Americas from Paraguay to Florida, in Africa, and also in India. In Uganda Wakefield & Hansford (1949) reported it on L. mollissima Gunge, L. nepetifolia and L. sp. from several localities.

Puccinia leucadis P. & H. Syd., Monogr. Ured. 1: 281, 1902.
On Leucas calystachys Oliv. (Lamiaceae)
Mubende Distr., Singo Co., 10 km NW of Katera, 1400 m, 16.03.1969, K.A. Lye (2306), Lester & Morrison, II.
On Leucas martinicensis (Jacq.) Ait.f.
W. Mengo Distr., Kyadondo Co., Kampala, Makerere Hill, 1200 m, 30.10.1968, K.A. Lye (12), II, Kabanyolo, 1200 m, Gj. (488), II, Mawokota Co., Mpanga Forest, 1150 m, Gj. (180), II; Mubende Distr., Singo Co., Kiboga, 1300 m, Gj. (307), II; Bunyoro Distr., Bugahya Co., Hoima, 1500 m, Gj. (330), II; Kigezi Distr., Bufumbira Co., on track to Gahinga, just below the forest boundary, 2500 m, Gj. (244a), II.

Uredinia amphigenous, rounded or oval, cinnamon-brown. Urediniospores mostly globoid, 25-31 x 24-31 µm, wall 2-3 µm thick, cinnamon-brown, distantly echinulate and with 3-5 pores.

The rust is widespread in Africa, and it is also reported from the Dominican Republic, India and China. Wakefield & Hansford (1949) reported it on both hosts mentioned above from a few localities from the Mt. Elgon area to Kigezi.

Puccinia lippiicola Pat. & Har., Bull. Soc. Mycol. Fr. 24: 13, 1908.
Syn. P. lippiivora H. & P. Syd. in Wildem. Flore Bas- et Moyen Congo 3, fasc. 1: 11, 1909; P. natalensis Diet. & H. Syd. var evansii Doidge, Bothalia 2: 82, 1926.
On Lippia grandiflora A. Rich. (Verbenaceae)
W. Mengo Distr., Busiro Co., 3 km SE of Jungo Church, 1140 m, K.A. Lye (1912) & M. Morrison, III; Bunyoro Distr., Bunyoro Ranching Scheme Area, 1100 m, 21.09.1961, B.J. Turner (209), III.
On Lippia plicata Bak.
Tanzania. Iringa Distr., Ruaha National Park, Magangwe Ranger Post, 1330 m, 09.03.1972, leg. A. Bjørnstad (1461, O) III.

Telia hypophyllous, round to oval, pulvinate, cinnamon-brown, greyish when germinated. Teliospores ellipsoid, not constricted at septum, (34-)43-52 x (16-) 19-26 µm, wall smooth, 1.5-3 µm thick, often unevenly, at apex thickened to 5.5 µm, pale yellow, upper pore apical, lower near septum, obscure. Pedicel hyaline, persistent, longer than the spore. One-celled spores fairly common.

P. lippiicola has been reported by Wakefield & Hansford (1949) on L. adoensis Hochst. from Kipayo in Kyagwe and Serere in Teso and on L. sp. from the Elgon area. Outside Uganda it is reported on Lippia spp. from Ghana, Zaire and Kenya southwards to South Africa. L. plicata appears to be a new host for this rust species.

Puccinia menthae Pers., Syn. Meth. Fung. p. 227,1801.
On Satureja pseudosimensis Brenan (Lamiaceae)
Kigezi Distr., Rubanda Co., Nyamabale, 2100 m, and Echuya Forest Reserve, Mile 33, 2100 m, Gj. (219, 239a), II, Bufumbira Co., Forest Reserve on track to Gahinga, 2700 m, Gj. (248), II.
On Satureja punctata (Benth.) Briq.
Kigezi Distr., Rubanda Co., Echuya Forest Reserve, Mile 33 from Kalsa, 2100 m, Gj. (239), II.
On Satureja simensis (Benth.) Briq.
Kigezi Distr., Rubanda Co., Mile 26 from Kabale on the Kabale-Kisoro road, 2100 m, Gj. (206), II.

Uredinia hypophyllous, round, oblong, confluent. Urediniospores obovoid or ellipsoid, 22-26 x 16-21 µm, wall 1-1.5 µm thick, pale cinnamon-brown to hyaline, echinulate with 2-3 equatorial, often obscure pores.

The only record of the worldwide distributed mint rust, living on a number of host generea of the Lamiaceae, was given by Wakefield & Hansford (1949) reporting it on Mentha aquatica L. from Kampala. The hosts mentioned seem to be new for the rust.

Puccinia natalensis Diet. H. & P. Syd., Hedwigia 38, Beiheft 3: 130, 1899.
On Lantana trifolia L. (Verbenaceae)
E. Mengo Distr., Bulemezi Co., Kiziba, 1200 m, Mugewyi (34); Bunyoro Distr., Bugahya Co., Hoima, 1500 m, Gj. (328); Ankole Distr., Nyabushozi Co., Muko Research Station, 1370 m, Gj. (119), all with III only.
Kenya. E. Prov., Nyeri Distr., Mt. Kenya, S. slope, Regati Forest Station, 2200-2300, 02.-03.02.1973, L. Ryvarden (9128, O), III.

Telia hypophyllous, rounded, pulvinate, dark brown. Teliospores ellipsoid to obovoid, slightly constricted at septum, rarely cylindric, 50-68 x (22-)30-34 µm, wall yellowish brown, smooth, 2.5-3.5(-4) µm thick, at apex thickened to 9.5 µm, upper pore apical, lower pore near septum. Pedicel wide, up to 170 µm long, hyaline.

This rust, described from S. Africa and later reported from Sudan and doubtfully from Ghana by Hughes (1952), has been recorded from several places in Uganda by Wakefield & Hansford (1949), also on L. trifolia. A record by Petrak (1959) on Lantana sp. from Tanzania is based on a misidentification of the host (cfr. Gilli 1972).

Puccinia necopina Grove, Bull. Misc. Inf. R. Bot. Gdns Kew

No. 10: 269-272, 1916.
On Tristemma incompletum R. Br. (Melastomataceae)
W. Mengo Distr., Mawokota Co., 2 km E of Bujoho on Mubende Road, 1180 m, K.A. Lye (1946), III.

Telia hypophyllous, densely aggregate, yellowish brown. Teliospores ellipsoid or clavate, constricted at septum, (34-)38-47 x (10-)14-18 µm, wall 1 µm thick, hyaline or very pale yellowish, smooth, pores not visible in ungerminated pores, upper pore apical, lower probably near septum. Pedicel hyaline, short.

P. necopina was described from Kipayo, and was later reported by Wakefield & Hansford (1949) from Kampala, in both cases on Tristemma sp.

Puccinia ocimi Doidge, Bothalia 2: 203, 1926.
Syn. Aecidium ocimi P. Henn., Bot. Jb. 17: 16, 1893.
On Ocimum suave Willd. (Lamiaceae)
Kenya. Eastern Prov., Nyeri Distr., Mt. Kenya S slope, Regati Forest Station, 2200-2300 m, 2.-3.2.1973, L. Ryvarden (9123, O), III.

Telia hypophyllous, irregular, confluent, compact, dark brown. Teliospores clavate to ellipsoide, slightly constricted at septum, 42-55 x 15-21 µm, wall (2.0-)2.5-3.5 µm thick, at apex thickened to 8.5 µm, golden brown, smooth. Pedicel hyaline to very pale yellow, long, persistent.

P. ocimi was reported on O. suave by Wakefield & Hansford (1949) from Kyasoweri in Elgon and from Serere in Teso, on O. sp. from Kampala while Ebbels (1972) reported it from Lake Mulehe in Kigezi. It is widespread on Ocimum spp. in Africa, from Ethiopia and Sudan to S. Africa. Outside Africa it is reported from Madagascar, Comoro Islands and India.

Puccinia pentadis-carneae Wakef. in Wakefield & Grove, Kew Bull. 74, 1916.
On Pentas lanceolata (Forsk.) Deflers (Rubiaceae)
Kigezi Distr., Rubanda Co., Nyamabale, 2100 m, Gj. (220), III.

Telia hypophyllous, round, scattered or in dense groups, compact, cinnamon-brown, when germinating paler. Teliospores fusiform, sometimes cylindric, slightly constricted at septum, 33-44 x 12-14 µm, wall 3-4 µm thick, at apex thickened to 8.5 µm, hyaline, smooth, upper pore apical, lower pore near septum. Pedicel hyaline, persistent.

This rust was described on Pentas carnea Benth. from Kipayo in Kyagwe and later reported from Kinyala in Bunyoro on the same host. P. lanceolata is a new host for this rust.

Puccinia rubiicola P. & H. Syd., Monogr. Ured. 1: 226, 1902.
On Rubia cordifolia L. (Rubiaceae)

Kenya. Central Prov., Thika Distr., 5 km WSW of Thika, at B. Harris Farm, 1500 m, 21.01.1970, L. Ryvarden (5628, O), II + III.

Uredinia amphigenous, long covered by epidermis, irregular, cinnamon-brown. Urediniospores subgloboid to broadly ellipsoid or obovoid, 28-37 x 22-32 µm, wall 2.5-3 µm thick, yellowish brown, echinulate and with 2 (rarely 3) equatorial pores covered by low, hyaline papillae. Telia epiphyllous, in uredinia, dark brown. Teliospores ellipsoid or clavate, rounded or attenuated at apex, slightly constricted at septum, (43-)54-62 x 19-26 µm, wall 1.5-2 µm thick, at apex thickened up to 15 µm, yellowish brown, but nearly hyaline at apex, smooth, pores obscure. Pedicel up to 75 µm long, hyaline.

P. rubiicola was described from Ethiopia and later reported by Wakefield & Hansford (1949) from Bufundi in Kigezi on the same host. It is new to Kenya. Mogk & Hindorf (1971) have reported *Puccinia collettiana* Barcl. on *P. cordifolia* from Kenya. This species which is reported from many localities in Asia from Pakistan, India, Nepal and China, and also Kirgezia and Kazakhstan in USSR, has a thinner urediniospore wall, by Nevodovsky (1956) measured to be 1-1.5 µm thick. This corresponds with what I have seen in specimens from Pakistan and India. It has also darker brown teliospores. *P. dimorpha* P. & H. Syd., described from S. Africa but also reported from Uganda on *R. condifolia*, has thinner urediniospore wall (1.5-2 µm, cfr. Doidge 1926) with 3 pores and longer teliospores.

P. rubiivora P. Magn., known only on *R. fruticosa* Ait. from the Canary Islands, has teliospores not or only slightly thickend at apex.

Puccinia ruelliae H. & P. Syd., Monogr. Ured. 1: 236, 1902.
Syn. *P. ruelliae* (Berk. & Br.) Lagh., Tromsø Mus. Aarsk. 17: 71, 1895, (III not described); *Uredo ruelliae* Berk. & Br., J. Linn. Soc. Bot. Lond. 14: 92, 1873.
On *Ruellia praetermissa* Lindau (syn. *R. patula* Jacq.) (Acanthaceae)
Bunyoro Distr., Bujenje Co., Bukumi, 750 m, Gj. (345), II + III.
On *Ruellia* sp.
Bunyoro Distr., Bujenje Co., Bukumi, 750 m, Gj. (348), II.

Uredinia amphigenous, scattered or in rings around a central sorus, cinnamon-brown. Urediniospores globoid to subgloboid, 23-33 x 21-28 µm, wall 2.5 µm thick, cinnamon-brown, echinulate and with 2 equatorial pores. Telia amphigenous, irregular, pulverulent, blackish brown. Teliospores ellipsoid, not constricted at septum, 37-48 x 30-33 µm, wall 2.5-4 µm thick, chestnut-brown, verrucose. Pedicel hyaline, often obliqually attached to the spore.

In the paper on rusts on Acanthaceae, Laundon (1963) listed several *Ruellia* spp. as hosts for the present species, and also *Asystasia* spp. and *Eranthemum variable* R. Br. in Africa and Asia. In Africa it is reported from Ethiopia, Ghana and the Ivory Coast, but it is new to

Uganda.

Viennot-Bourgin (1953) following Arthur (1934) discussed this rust under the name P. ruelliae (Berk. & Br.) Lagh. including some American species which Laundon (op.cit.) maintained as separate species. A uredinial stage on Lepidagathis laguroidea T. Anders from the Ivory Coast, by Viennot-Bourgin (1958) placed within the same species, Laundon (op.cit.) listed as Uredo sp. Laundon also discussed the nomenclature.

Puccinia semiloculata Laundon, Mycol. Pap. 69: 61, 1963.
On Justicia sp. (Acanthaceae)
Kenya. Eastern Prov., Nyeri Distr., Mt. Kenya, S slope, Regati Forest Station, 2200-2300 m, 2.-3.2.1973, L. Ryvarden (9121, O), I + III.

Aecia hypophyllous, in small groups. Peridia white, revolute. Aeciospores ovoid, subgloboid or angular, 16-22 x 12-18 µm, wall 1 µm thick, hyaline, verruculose and with refracting granules. Telia hypophyllous, small, rounded, confluent, brown. Teliospores cylindrical, clavate or fusiform, slightly constricted at septum, attenuate, rarely truncate at apex, 36-49 x 12-16 µm, wall nearly hyaline, smooth, 1 µm thick, at apex thickened up to 7 µm. Pedicel hyaline, persistent.

The following specimens have only aecia. According to Laundon (1963) P. semiloculata and P. thunbergiae M.C. Cooke cannot be distinguished when lacking telia. The lack of pycnia separate them from Aecidium justicia P. Henn.
On Justicia flava (Forsk.) Vahl.
W. Mengo Distr., Busiro Co., Entebbe, 1150 m, Gj. (17), Kyadondo Co., Kazi, 1160 m, Gj. (55); Bugisu Distr., N. Bugisu Co., Bulambuli Escarpment, 1700 m, Gj., (396).
Kenya. Central Prov., Mt. Elgon, Suam Forest Station, 2100 m, 23.-24.2.1973, L. Ryvarden (9275, O).
On Justicia exigua S. Moore
Teso Distr., Soroti Co., Arapai Research Station, 1100 m, Gj. (419).
On Justicia striata (Klotzsch) Bullock or J. unyorensis S. Moore
W. Mengo Distr., Mawokota Co, Mpanga Forest, 1150 m, Gj. (183); E. Mengo Distr., Buruli Co., S of Katugo, 1150 m, Gj. (368),
On Justicia stricta (Klotsch) Bullock
W. Mengo Distr., Busiro Co., Entebbe 1150 m, Gj. (30), and Zika Forest, 1160 m, Gj. (72).
On Justicia sp.
Bugisu Distr., N. Bugisu Co., Forest Reserve Boundary on track to Sasa Hut, 2500 m, Gj. (394).

Puccinia stobaeae Mac Owan var. woodii P. & H. Syd., Monogr. Ured. 1: 160, 1902.
On Berkheya spekeana Oliv. (Asteraceae)
Karamoja Distr., Matheniko Co., SE of Sogolomon, Mt. Moroto, 2300 m, 11.06.1970, K.A. Lye (M 18A), 0+I; Mubende

Distr., Singo Co., Mile 70 on the Hoima road, 1400 m, Gj. (298), II+III; Bunyoro Distr., Bugahya Co., Hoima, 1500 m, Gj. (323), II+III; Toro Distr., Kyaka Co., Mile 116 on Fort Portal road, 500 m, Gj. (493), I.

Pycnia epiphyllous. Aecia hypophyllous, in small groups. Peridium white, long, revolute, lacerate. Aeciospores subgloboid, ellipsoid or irregular, 24-38 x 20-31 µm, wall 1 µm thick, hyaline, with large prismatic warts. Uredinia mainly hypophyllous, cinnamon-brown. Urediniospores subgloboid, 36-42 x (30-)33-38 µm, wall 2.5-3 µm thick, yellowish brown, with scattered, long spines, and 3-5 pores with hyaline papillae, equatorial or scattered. Telia hypophyllous rounded or oval on veins, pulvinate, dark brown. Teliospores ellipsoid with rounded ends, rarely obovoid, slightly constricted at septum, 40-52(-64) x 32-40 µm, wall cinnamon-brown, in lower cell 1.5-2 µm thick, in upper cell 2.5-3 µm, at apex thickened to 5.5 µm, finely verrucose, rarely smooth, upper pore apical. Pedicel long as the spores, but often broken short under the spore.

This rust is new to Uganda. Both varieties are previously known only from S. Africa. The var. *woodii* has urediniospores with thinner wall than has the var. *stobaeae*. The teliospores of var. *woodii* are shorter than those of var. *stobaeae*, and with a wall distinctly thicker in the upper cell than in the lower one while they in the var. *stobaeae* are of evenly thickness.

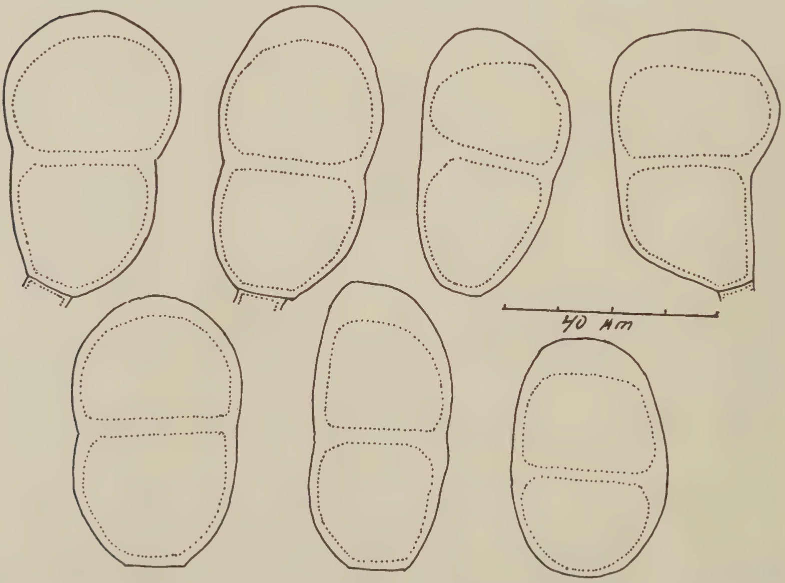


Fig. 7. *Puccinia tetradeniae* n.sp.
Teliospores from type.

Puccinia tetradeniae n.sp. (Fig. 7)

Pycnia, aecia et uredinia non visa. Telia hypophylla, parva, castaneo-brunnea. Teliosporae obclavatae, ellipsoideae vel irregulares, ad septum leviter vel non constrictae, 43-60 x 23-35 µm, pariete 1-1.5 µm crasso, ad apicem usque 8 µm incrassato, brunneo, laeve, poro superiore apicali, poro inferiore prope septum instructis, pedicello hyalino, usque 80 µm longo, hyalino, deciduo.
Holotype: S.B. Manum 71-12 (MHU), 12.07.1971, Tanzania, Distr. Njombe T., Nyantyla River, on *Tetradenia riparia* (Hochst.) Codd (Lamiaceae). Isotype in NPPI.

To my knowledge no rust has been described neither on this genus nor on related genera in the Stachyoideae - Podostemoneae tribe (Engler & Prantl System).

Puccinia thunbergiae M.C. Cooke, Grevillea 10: 125, 1882.
On *Asystasia gangetica* (L.) T. Anders. (Acanthaceae)
W. Mengo Distr., Kyadondo Co., Kazi, 1160 m, Gj. (59), II; E. Mengo Distr., Buruli Co., S of Katugo, 1150 m, Gj. (366), II.
Kenya. Eastern Prov., Nyeri Distr., Mt. Kenya, S slope, Regati Forest Station, 2200-2300, 2.-3.2.1973, L. Ryvarden (9110, O), I +III.
On *Asystasia schimperi* T. Anders.
W. Mengo Distr., Kyadondo Co., Namulonge, 1200 m, Gj. (94), II, Kabanyolo, 1200 m, Gj. (285), II; Toro Distr., Busongora Co., Mweya Lodge, 930 m, Gj. (149), II.
On *Dicliptera* sp. (Acanthaceae)
Sebei Distr., Reg. Mt. Elgon, near Mutusyet, 20.01.1969, K.A. Lye (1559), I.
On *Thunbergia* cf. *alata* Boj. ex Sims. (Acanthaceae)
Kigezi Distr., Rubanda Co., Echuya Forest Reserve, Mile 33 from Kabale, 2100 m, Gj. (237), I.

Aeciospores angular, 12-24 x 9-20 µm, wall 0.5-1 µm thick, irregularly but delicately verrucose, with a few refracting granules, hyaline. Telia hypophyllous, crust-like, dark brown. Teliospores varying in shape, cylindric, clavate or fusiform, truncate or acute at apex, 35-47 x 12-15 µm, wall 1-2 µm, at apex thickened up to 5.5 µm, yellowish, smooth. Pedicel hyaline, persistent.

The specimens reported by Wakefield & Hansford (1949) as *Aecidium acanthacearum* Cooke on *Justicia* spp. were all placed with *P. thunbergiae* by Laundon (1963). The hosts mentioned above seem to be new to Uganda, but *A. gangetica* and *A. schimperi* have been reported from Tanzania (Ebbels & Allen 1979). They also recorded *Dicliptera* sp., a genus serving as a host for this rust in India and Celebes. *T. alata* is type host for *P. thunbergiae-alatae* P. Henn., reported from Namanyonyi in Kyagwe, but the same specimen was listed from Malawi by Laundon (1963). *P. thunbergiae-alatae* has aeciospores with 2-3 µm thick wall. In the *T.* cf. *alata* specimen studied by me the wall is hardly above 1 µm thick, thus corresponding well to *P. thunbergiae*. Other African *Thunbergia* species serving as hosts for this rust are *T. atriplicifolia* E. Mey., *T. natalensis* Hook and

T. usambarica Lindau.

Puccinia vernoniicola P. Henn. in Engl. Ostafrikan. Pflanzenwelt p. 50, 1895.
On Vernonia sp. (Asteraceae)
W. Mengo Distr., Mawokota Co., Mpanga Forest, 1150 m, Gj. (185), III.

Telia hypophyllous, irregular, confluent, compact, yellow-brown, white when spores germinate. Teliospores ellipsoid or clavate, lower cell longer than the upper one, 50-67 x 17-25 µm, wall 1 µm thick, at apex thickened to 4 µm, hyaline to very pale yellowish, smooth, upper pore apical, lower near septum. Pedicel hyaline, 40 µm long, persistent.

This rust, described from Kilimanjaro in Tanzania, was reported by Wakefield & Hansford (1949) on V. sp. from Rifle Range in Kiagwe and Kiterera in Busoga. It is also known from Kenya and S. Africa.

Pucciniosira dissotidis Wakef., Kew Bull., p. 313, 1917.
On Dissotis irvingiana Hook.f. (Melastomataceae)
Mubende Distr., Singo Co., Lwangeta Swamp, W of Kiboga, Gj. (313), III.

Telia hypophyllous, cylindrical, in dense groups, with a peridium. Teliospores in chains, 2-celled, falling easily apart, ellipsoid, 22-29(-35) x 12-17 µm, wall 1 µm thick, hyaline, smooth.

This rust was described by Cooke (1882) as both Aecidium dissotides and Uredo dissotidis. However, the Sydows (1924) found that it was all the same with the species described by Wakefield (loc.cit.) on D. incana and D. sp. from Kyagwe. Later, Wakefield & Hansford (1949), reported it on D. sp. from Kabaroni in Elgon and from Kisoro in Kigezi. It is widespread in Africa on Dissotis spp. and it is also reported on Imbemma sp. from Cameroon (Heim 1951).

Uredo clerodendrina Vien.-Bourg., Uredineana 5: 231, 1958.
Syn. U. clerodendricola Vien.-Bourg. non P. Henn., Bull. Soc. Mycol. Fr. 70: 418, 1954.
On Clerodendron myricoides (Hochst.) Vathe (Verbenaceae)
Bugisu Distr., N. Bugisu Co., Bumasifwa, 1300 m, Gj. (406), I+II.

Aecia hypophyllous, in small groups, peridium white, revolute, lacerate. Aeciospores subgloboid, ellipsoid or ovoid, 22-28 x 15-21 µm, wall 1(-1.5) µm thick, hyaline, densely verrucose. Uredinia amphigenous, round, scattered or in small groups, cinnamon-brown. Urediniospores subgloboid, ellipsoid or ovoid, 19-31 x 16-19(-23) µm, wall 1 µm thick, sparcely echinulate, and with two equatorial pores covered with low hyaline papillae, often obscure.

In the original diagnosis only uredinia are described. The present material has aecia in close connection with the uredinia, and they no doubt belong to the same species.

U. clerodendrina was described from the Ivory Coast. Later it is reported also from Ghana. *C. myricoides* is a new host for this rust which is new to the flora of Uganda.

Uredo cf. humbertii Maire, Bull. Soc. Bot. Fr. 81: 646, 1934.
On *Helichrysum cf. gerberifolium* Sch. Bip. (Asteraceae) Karamoja Distr., Matheniko Co., Mt. Morimoto, SE of Sogolomon, 2300 m, 11.6.1970, K.A. Lye (M 18 B), II.

Uredinia hypophyllous, round, yellow, surrounded by the brown, cracked epidermis. Urediniospores ellipsoid to broad obovoid or subgloboid, 27-32 x 23-27 µm, wall 2-2.5 µm thick, very pale yellow, delicately and densely echinulate, pores obscure, probably 3-5, scattered.

Bouriquet & Bassino (1965) studying the type specimen, found larger urediniospores, 40-42 x 34-36 µm, with slightly thicker wall, 3 µm.

This rust is previously known only from Madagascar on *H. vaginatum* Humbert.

Uredo hypoëstis-verticillaris n.sp. (Fig. 8)

Uredinia hypophylla, irregularia, dispersa vel in gregibus parvis, pallide cinnamomea, epidermide longe obtecta. Urediniosporae subgloboideae, obovoideae, 20-27 x 17-20 µm, pariete 1.5 µm crasso, hyalino, echinulato, poris obscuris (duobus equatorialibus instructis?).
Holotype: E. Lang Braun 60a (MHU), Uganda, Karamoja Distr., Mt. Moroto, 2700-2800 m, 26.02.1960 on *Hypoëstes verticillaris* (L.f.) Soland. ex Roem. & Schult. (Acanthaceae). Isotype in NPPI.

Laundon (1963) when monographing the rusts on Acanthaceae, listed only one species with uredinia on *Hypoëstes*, viz. *Uromyces hypoëstis* Tarr & Laundon. This species has larger urediniospores (28-26 x 22-30 µm) with an amber-coloured, thicker wall (1.5-2.5 µm) and 2 approximately equatorial pores. The new species has a hyaline spore wall which also is more densely echinulate.

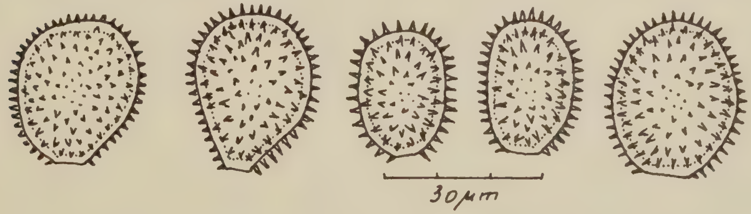


Fig. 8. *Uredo hypoestis-verticillaris* n.sp.
Urediniospores from type.

Uredo isoglossae n. sp. (Fig. 9)

Uredinia hypophylla, irregularia, dispersa, epidermide pallide brunnea longe obtecta. Urediniosporae subgloboideae ad obovoideae vel ellipsoideae, 26-32 x (16-) 21-26 µm, pariete 1-1.5 µm crasso, hyalino, dense echinulato, duobus poris equatorialibus instructis, obscuris.
Holotype: L. Ryvarden 9120 (O) 02.-03.02.1973, Kenya, Eastern Prov., Nyeri Distr., Mt. Kenya, S slope, Regati Forest Station, 2200-2300 m on Isoglossa substrobilina C.B. Cl. (Acanthaceae).

Laundon (1963) mentioned only the South African species Uredo ecteinanthi Kalchbr. having uredinia on Isoglossa (Ecteinanthus = Isoglossa), but this rust species has spores with a yellow-brown and sparsely echinulate wall. Another species, Uredo mitteri (Syd.) Laundon, described as Coleosporum mitteri Syd. from India on an Acanthaceae indet., has acc. to the diagnosis similar but smaller spores than has U. isoglossae which uredinia are similar to those found in Coleosporium.

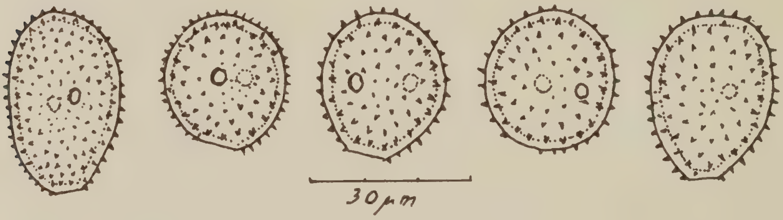


Fig. 9. Uredo isoglossae n.sp.
Urediniospores from type.

Uredo leucadicola n.sp. (Fig. 10)

Pycnia amphigena, typus 4. Aecia in maculas brunneas, amphigena, pro maxima parte epiphylla, dispersa in gregibus parvis vel in annulis circa pycnia, peridio albo, tubiformi. Cellulae peridii plus minusve rectangulares, pariete externo striato, 5 µm crasso, pariete interno, verrucoso, 3 µm crasso. Aeciosporae subgloboideae ad ellipsoideae vel irregulariae, 22-27 x 16-23 µm, pariete 1.5 µm crasso, hyalino, dense verrucoso. Uredinia amphigena, irregularia, pallide cinnamomea. Urediniosporae ellipsoideae ad subgloboideae, 22-25 x 18-23 µm, pariete 1 µm crasso, pallide cinnamomeo, echinulato, poris duobus vel tribus dispersis instructis, obscuris.
Holotype: H.B. Gjærum 252 (MHU), 02.10.1970, Uganda, Kigezi Distr., Bufumbira Co., at the saddle between Muhavusa and Gahinga, 3100 m, on Leucas martinicensis (Jacq.) R. Br. (Lamiaceae).
Other specimen seen:
Kenya. Central Prov., Mt. Elgon, Suam Forest Station, 2100

m, 24.01.1973, L. Ryvarden (9267, O), II.

Uredinia and its spores are much brighter and the spore wall thicker than are those of *P. leucadis* P. & H. Syd., which also is lacking aecia.

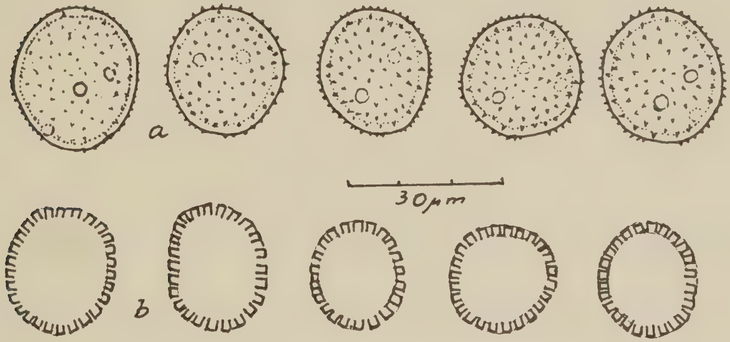


Fig. 10. *Uredo leucadicola* n.sp.
a. Urediniospores. b. Aecidiospores.
From type.

Uredo paederiae P. & H. Syd., Öst. bot. Z. 52: 184, 1902.
On *Paederia foetens* (Hiern) Schum. (Rubiaceae)
Tanzania. Iringa Distr., near Great Ruaha River, 9 km W of Kidater Bridge, 13.7.1970, M. Thulin & B. Mhoro (399, ex herb. O), II.

Uredinia hypophyllous, scattered or in groups on reddish to brown leaf spots, sori cinnamon-brown. Urediniospores subgloboid to angular, often triangular or quadratic in side view, 22-28 x 18-25 µm, wall 1 µm thick, cinnamon-brown, densely echinulate and with 2-4 scattered pores.

In the diagnosis the Sydows did not mention pores while Yen (1970) said they were obscure. In the present specimen indistinct pores covered by low, hyaline papillae are recognized in most spores.

U. paderiae described on *P. foetida* L. from the Comores, has later been reported scattered on several *P.* spp. from India to Ryukyu Islands. It is new to the rust flora of Africa, and *P. foetens* is a new host.

Uredo palpigera Cumm., Bull. Torrey Bot. Club 72: 221, 1945.
On *Inula decipiens* E.A. Bruce (Asteraceae)
Mubende Distr., Singo Co., Mile 112 on Kampala-Hoima Road, near the border of Bunyoro Distr., 1000 m, Gj. (320) II.

Uredinia amphigenous, irregular, long covered by epidermis, with hyaline, thin walled paraphyses, thickened at apex. Urediniospores obovoid or ellipsoid, 21-27 x 18-23 µm, wall 1-1.5 µm thick, hyaline or very pale cinnamon-brown, echinulate, pores obscure.

This species is previously known only from the type locality, viz. in Kigezi, type host is I. acervata S. Moore. Cummins (1945) indicated that U. palpigera and some other similar Uredo spp. probably would be placed in the genus Phakopsora when telia were found.

Uromyces aspiliicola Cumm., Bull. Torrey Bot. Club 72: 208, 1945.
On Aspilia africana (Pers.) C.D. Adams. (Asteraceae)
W. Mengo Distr., Busiro Co., Zika Forest, 1160 m, Gj. (69), II; Toro Distr., Kyaka Co., Mile 127 on the road Kampala-Fort Portal, W of Nabingora, 1500 m, Gj. (162), II; Bunyoro distr., Bugahya Co., Hoima, 1500 m, Gj. (329), II.

Uredinia hypophyllous, cinnamon-brown. Urediniospores obovoid, sometimes wider than long, 23-30 x 22-30 µm, wall 1.5-2 µm thick, in some spores slightly thicker at the base, cinnamon-brown, delicately echinulate and with 2 equatorial pores.

The rust was described from Kabarmi in the Elgon area and also mentioned by Wakefield & Hansford (1949). Outside Uganda it is reported on A. hotschyi from Tanzania and Zambia, and from Sudan on Guizotia spp. More doubtful seems a report on Wedelia sp. from Malawi (cf. e.g. Bisby & Wiehe 1953). A. africana is a new host for the rust.

Uromyces bidenticola Arth., Mycologia 9: 71, 1917.
Syn. Uredo bidenticola P. Henn., Hedwigia 37: 279, 1898.
On Bidens hirsuta L. (Asteraceae)
W. Mengo Distr., Kyadondo Co., Makerere, 1200 m, Gj. (10), II.

Uredinia hypophyllous, round or oblong, brown. Urediniospores obovoid to ellipsoid, (22-)25-32 x 17-24 µm, wall 1.5 µm thick, cinnamon-brown, echinulate, 2 pores with low papillae, equatorial or slightly superequatorial.

This rust, widespread in tropical and subtropical areas, was reported by Wakefield & Hansford (1949) from Kipayo in Kyagwe, Nkokonjeru in Bugishu and Kabale in Kigezi. Telia are rarely found in the Eastern Hemisphere (cf. Gjærum 1986).

The urediniospore wall thickness is often given as 2-2.5 µm.

Uromyces blainvilleae Berk., J. Linn. Soc. Bot. Lond. 15: 92, 1875.
On Blainvillea gayana Cass. (Asteraceae)
Tanzania. Iringa Distr., Ruaha National Park, 3 km N of Msembe, 27.04.1971, leg. A. Bjørnstad (956, O), II + III.

Uredinia hypophylla, brown. Urediniospores subgloboid, ellipsoid or somewhat angular, 19-26 x 19-23 µm, wall 1.5-2 µm, echinulate, cinnamon-brown, with (2-)3(-4) scattered pores. Telia amphigenous, irregular, often confluent, dark brown. Teliospores subgloboid, 35-38 x 31-37 µm, wall chestnut brown, paler at apex, verrucose, 4.5-5.5 µm thick, at apex thickened to 9 µm, pore apical. Pedicel hyaline, long, persistent.

This rust has been reported several times from India and Brazil mainly on B. rhomboideae Cass. (=B. latifolia DC.), but also on other Blainvillea spp., and it is also reported from Galapagos. In Africa it is reported from Ethiopia, Sudan, Nigeria, and Senegal, form the last mentioned country on B. gayana (Mayor 1964).

Uromyces hobsonii Vize, Grevillea 4: 115, 1876.
On Jasminum dichotomum Vahl (Oleaceae)
Toro Distr., Kyaka Co., Mile 127 on the Kampala-Fort Portal road, 1500 m, Gj. (161), I.
On Jasminum eminii Gilg.
Mubende Distr., Singo Co., Mile 101 on Kampala-Hoima road, 1400 m, Gj. (321), I.
On Jasminum meyeri-johannis Engl.
Tanzania. Kilimanjaro, Mwika, 02.01.1960, Bakari B.M. (46) 0+I+III.

Aecia hypophyllous, often making small tumours. Peridium white, revolute. Aeciospores ovoid or angular, 14-22 x 13-15 µm, wall 1-1.5 µm thick, verruculose, hyaline. Telia in aecia, dark brown. Teliospores ellipsoid, rarely subgloboid, 41-47(-58) x 28-33(-37) µm, wall 6-6.5 µm thick, at apex thickened to 9 µm, pale brown. Pedicel hyaline, later pale brown, thick-walled.

This rust, described from and widespread in India, was reported by Wakefield & Hansford (1949) on J. dichotomum and J. sp. from several localities in Uganda. It has a wide distribution in Africa, and in Asia it is also reported from Afghanistan, Nepal and the Philippines. J. eminii is a new host for this rust.

Uromyces ipomoeae Berk. in Kalchbrenner, Grevillea 11: 19, 1882.
On Ipomoea tenuirostris Choisy (Convolvulaceae)
Bugisu distr., N. Bugisu Co., Bumasobo, 1500 m, Gj. (401), II.

Uredinia amphigenous, round to elliptical, scattered or in groups, cinnamon-brown. Urediniospores globoid to obovoid, 28-33 x 18-27 µm, wall pale cinnamon-brown to cinnamon-brown, 3-3.5 µm thick, echinulate, with 2-4 pores, when 2 equatorial, when 3-4 scattered.

U. ipomoeae was reported by Wakefield (1920) on a Convolvulaceae, and later by Wakefield & Hansford from several localities in Uganda, including I. tenuirostris from Kabale in Kigezi. In Africa it is known from Sudan, Kenya, Malawi, and S. Africa, and it is also known from Indonesia.

Uromyces melantherae Cooke, Grevillea 10 (1881/82): 127, 1882.
On *Melanthera scandens* (Schum. & Thonn.) Roberty (Asteraceae)

Uredinia amphigenous, scattered, cinnamon-brown. Urediniospores subgloboid, 23-26 x 21-23 µm, wall yellowish brown, 1.5 µm thick, sparcely echinulate with 3 scattered, often obscure pores. Teliospores in the uredinia, lanceolate oblong to oval, rarely obovoid, 31-45 x 20-24 µm, wall less than 1 µm thick, at apex thickened to 11 µm, yellowish brown, smooth, pore apical. Pedicel hyaline, persistent, often longer than the spore.

Doidge (1926) described the urediniospore wall as about 3 µm thick, and the teliospores somewhat narrower (14-18 µm) than seen in the specimen studied by me.

Wakefield (1920) reported this rust from on *M. brownei* Sch. Bip. from Kipayo and on *M.* sp. from Namanyonyi, both localities in Kyagwe Co. Later Wakefield & Hansford (1949) added *M. pungens* Oliv. & Hiern from Katakwi in Teso to the list. *M. scandens* is a new host in Uganda, but Mogh & Hindorf (1971) reported it on the ssp. *madagascariensis* (Bak.) Wild from Kenya. On *M. brownei* it is also reported from Ghana and S. Africa.

Uromyces sasaënsis n.sp. (Fig. 11)

Pycnia amphigena in maculis foliorum flavis, 110 µm lata, typus 4. Aecia amphigena, usque 250 µm lata, dispersa vel in annulis circa pycnia, peridio albo, revoluto, aliquot lacerato. Cellulae peridii rectangulares vel rhombiformes, 30-40 x 14-16 µm, pariete interno 3-4 µm crasso, verruculoso, pariete externo 3-4 µm crasso, striato. Aeciosporae subgloboideae vel ellipsoideae, aliquot angulariae, 14-27 x 12-20 µm, pariete 1-1.5 µm crasso, hyalino, dense verruculoso, poris obscuris. Uredinia amphigena, rotundata vel ovalia, cinnamomea. Urediniosporae ellipsoideae vel globoideae 28-34 x 26-29 µm, pariete 1.5 µm crasso, cinnamomeo dense echinato, spinis fragilibus usque 3.5 µm longis, 2-4 poris subequatorialibus instructis, aliquot obscuris. Telia hypophylla, rotundata vel ellipsoidea, dispersa, cinnamomea. Teliosporae obovoideae vel ellipsoideae, 25-38 x 22-29 µm, pariete 1-1.5 µm crasso, ad apicem usque 2.5 µm incrassato, cinnamomeo, laevi, poro apicali, pedicello hyalino, pariete tenui, collabente, usque 65 µm longo, saepe brevi fracto.
Holotype: H.B. Gjærum 376 (MHU), Uganda, Bugisu Distr., N. Bugisu, Mt. Elgon, Sasa Hut, 3250 m, 23.10.1970, On *Valeriana volkensii* Engl. (Valerianaceae). Isotype in NPPI.
Other material:
On *Valeriana kilimandscharica* Engl.
Bugisu Distr., N. Bugisu Co., Mt. Elgon, Sasa Hut, 3250 m, Gj. (377), II.

Two *Uromyces* spp. are previously described on *Valeriana*, viz. *U. valerianae* (DC.) Fuck. and *U. valerianae-wallichii* Arth. & Cumm. Their urediniospores have thicker walls which are finely echinulate. The teliospores of the former are smaller than those of U. sasaënsis with short pedicel while those in the latter have scattered, obtuse warts (S. Ahmad 1956).

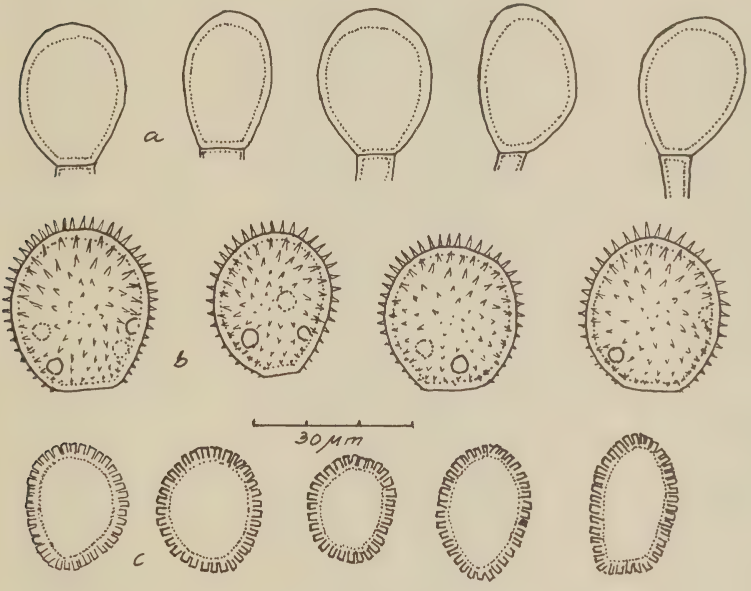


Fig. 11. Uromyces sasaënsis n.sp.
a. Teliospores. b. Urediniospores.
c. Aeciospores. From type.

Host-rust index

In this index are listed the host-rust combinations published in the papers dealing with the East African rust fungi (Gjærum 1983, 1984, 1984a, 1985). The page numbers refer to the fungi.

Abutilon	Puccinia abutili	4: 245
Acacia	Ravenelia hansfordii	4: 263
Acalypha	Physopella hansfordii	4: 244
Achyranthes	Uredo achyranthicola	4: 264
Aframomum	Puccinia aframomi	4: 245
Albizia	Ravenelia albiziae-zygiae	4: 263
Ammocharis	Aecidium hartwegiae	3: 65
Andropogon	Puccinia eritraeensis	1: 219
Aneilema	Uromyces commelinae	3: 68
Anthephora	Puccinia chaseana	1: 216
Anthriscus	Puccinia anthriscicola	4: 246
	Puccinia chaerophylli	4: 247
Artemisia	Puccinia artemisiae-afrae	5: 518
Arthraxon	Puccinia arthraxonis-ciliaris	1: 214
Asparagus	Puccinia phyllocladiae	3: 67
	Uredo kabanyoloensis	3: 68, 5: 550
Aspilia	Aecidium aspiliae	5: 508
	Uromyces aspiliicola	5: 540
Asystasia	Puccinia thunbergiae	5: 535
Barleria	Puccinia lantanae	5: 526
Becium	Puccinia becii	5: 520
Berkheya	Puccinia stobaeae var. woodii	5: 533
Bidens	Uromyces bidenticola	5: 540
Blainvillea	Uromyces blainvilleae	5: 540
Bothriochloa	Puccinia duthiae	1: 218
	Uromyces clignyi	1: 228
Brachiaria	Physopella africana	1: 212
	Puccinia levis var. panici-sanguinalis	1: 221
	Uromyces setariae-italicae	1: 232
Bromus	Puccinia recondita	1: 225
Canthium	Hemileia canthii	5: 514
Carex	Puccinia petitiana	2: 60
	Uredo caricis-confertae	2: 60
	Uredo montis-elgonensis	2: 61
Cassia	Aecidium torae	4: 240
	Ravenelia cassiaecola var. berkeleyi	4: 263
Celosia	Aecidium celosiae	4: 238
Cenchrus	Puccinia cenchri var. africana	1: 215
Cerastium	Puccinia arenariae	4: 247
Chloris	Puccinia dietelii	1: 218
	Uromyces keniensis	1: 230
Chrysopogon	Puccinia duthiae	1: 218
Clematis	Aecidium englerianum	4: 238
	Coleosporium clematidis	4: 240
Clerodendron	Endophyllum superficiale	5: 514
	Hemileia scholzii	5: 515
	Uredo clerodendrina	5: 536

Clutya	Uromyces cluytiae	4: 266
Coffea	Hemileia vastatrix	5: 515
Commelina	Physopella tecta	3: 66
	Uromyces commelinae	3: 68
Conyza	Aecidium macowanianum	5: 512
Crassocephalum	Aecidium gynurae	5: 510
	Puccinia crassocephali	5: 521
Crotalaria	Uromyces crotalariae	4: 267
Cyanotis	Uromyces commelinae	3: 68
Cyathula	Puccinia cyathulicola	4: 248
Cymbopogon	Puccinia andropogonis	1: 214
	Puccinia nakanishikii	1: 223
Cynanchum	Aecidium cynanchi	5: 508
Cynodon	Puccinia cynodontis	1: 216
Cyperus	Puccinia conclusa	2: 53
	Puccinia cyperi-cristati	2: 54
	Puccinia cyperi-tagetiformis	2: 55
	Puccinia morotoensis	2: 57
	Uromyces notabilis	2: 62
Deschampsia	Puccinia brachypodii var. arrhenatheri	1: 214
Desmodium	Uredo desmodii-ramosissimi	4: 265
Dicliptera	Puccinia thunbergiae	5: 535
Dicrocephala	Aecidium dichrocephalae	5: 509
Digitaria	Puccinia digitariae-velutinae	1: 217
	Puccinia oahuensis	1: 224
	Uromyces pegleriae	1: 231
Dipcadi	Uromyces dipcadi	3: 70
Dissotis	Pucciniosira dissotidis	5: 536
Droguetia	Puccinia fusispora	4: 249
Drymaria	Puccinia leptosperma	4: 251
Echinops	Puccinia dummeri	5: 523
Eragrostis	Physopella hiratsukae	1: 213
	Uredo sp.	1: 228
Erlangea	Physopella wiehei	5: 517
	Puccinia erlangeae	5: 523
Eriochloa	Uromyces setariae-italicae	1: 232
Eulophia	Uromyces eulophiae	3: 71
Euphorbia	Melampsora euphorbiae	4: 243
	Uromyces euphorbiae	4: 268
Evolvulus	Puccinia desertorum	5: 522
Fimbristylis	Puccinia fimbristylidis	2: 56
Fuirena	Puccinia cyperi-tagetiformis	2: 55
	Uredo fuirenae-strictae	2: 61
Galium	Puccinia difformis	5: 522
Geranium	Puccinia leveillei	4: 252
	Uromyces geranii	4: 268
Gladiolus	Uromyces transversalis	3: 71
Gossypium	Phakopsora gossypii	4: 243
Guizotia	Puccinia guizotiae	5: 524
Haplocarpha	Aecidium haplocarphae	5: 511
Helichrysum	Aecidium echuyaënsis	5: 509
	Physopella nyasalandica	5: 517
	Puccinia kalchbrenneri	5: 526
	Uredo cf. humbertii	5: 537
Helictotrichon	Puccinia coronata	1: 216

Heteropogon	Puccinia versicolor	1: 226
Hibiscus	Puccinia exilis var. hibisci	4: 248
	Puccinia garckiana	4: 250
Hoslundia	Puccinia hoslundiae	5: 525
Hyparrhenia	Phakopsora incompleta	1: 210
	Puccinia andropogonicola	1: 213
	Puccinia eritraeensis	1: 219
	Puccinia eucomi	1: 220
	Puccinia hyparrheniae	1: 221
	Puccinia versicolor	1: 226
	Uromyces clignyi	1: 228
	Uromyces hyparrheniae	1: 229
Hypericum	Puccinia keniensis	4: 251
Hyperthelia	Puccinia andropogonicola	1: 213
	Puccinia versicolor	1: 226
Hypoëstes	Puccinia isoglossae	5: 526
	Uredo hypoëstis-verticillaris	5: 537
Impatiens	Dietelia impatientis	4: 241
Imperata	Puccinia fragosoana	1: 221
Indigofera	Ravenelia indigoferae	4: 264
	Uromyces indigoferae	4: 269
Inula	Uredo palpigera	5: 539
Ipomoea	Puccinia holosericea	5: 525
	Uromyces ipomoeae	5: 541
Isoglossa	Uredo isoglossae	5: 538
Jasminum	Uromyces hobsonii	5: 541
Justicia	Puccinia semiloculata	5: 533
Lantana	Puccinia natalensis	5: 530
Leonotis	Puccinia leonotidicola	5: 528
Leucas	Puccinia leucadis	5: 529
	Uredo leucadicola	5: 538
Lippia	Puccinia lippiicola	5: 529
Loranthus	Aecidium ? cookeanum	4: 238
Loudetia	Phakopsora loudetiae	1: 211
	Puccinia loudetiae	1: 222
Luzula	Puccinia obscura	3: 66
Medicago	Uromyces striatus	4: 270
Melanthera	Uromyces melantherae	5: 542
Melinis	Uromyces setariae-italicae	1: 232
Microglossa	Puccinia aecidiiformis	5: 517
Mitracarpus	Puccinia bakoyana	5: 520
Monanthotaxis	Aecidium popowiae	4: 239
Murdannia	Uromyces commelinae	3: 68
Ocimum	Puccinia ocimi	5: 531
Oplismenus	Puccinia flaccida	1: 220
Ornithogalum	Aecidium ornithogaleum	3: 66
Oxygonum	Puccinia polygoni-amphibii	4: 260
Paederia	Uredo paederiae	5: 539
Panicum	Physopella cameliae	1: 212
	Uromyces linearis	1: 231
	Uromyces setariae-italicae	1: 232
Paspalum	Puccinia emaculata	1: 219
Pavetta	Aecidium flavidum	5: 510
Pelargonium	Puccinia pelargonii-zonalis	4: 254
Pennisetum	Phakopsora apoda	1: 210
	Puccinia cenchri var. africana	1: 215

Pentas	Puccinia pentadis-carneae	5: 531
Peucedanum	Puccinia pelargonii-elgonensis	4: 254
	Puccinia peucedani-kerstenii	4: 257
Phaseolus	Uromyces appendiculatus	4: 266
Pilea	Puccinia fusispora	4: 249
Plectranthus	Aecidium plectranthi	5: 513
Poa	Puccinia brachypodii var. poae-nemoralis	1: 215
Polygonum	Puccinia polygonii-amphibii	4: 260
Pseudarthria	Uromyces pseudarthriae	4: 269
Pseudechinolaena	Puccinia pseudechinolaenae	1: 225
Psychotria	Hemileia holstii	5: 515
Pycnostachys	Aecidium pycnostachydis	5: 513
Ranunculus	Aecidium ranunculacearum	4: 239
Rhamnus	Endophyllum (?) striatosporum	5: 514
Rhynchelytrym	Puccinia digitariae-velutinae	1: 217
	Puccinia levis var. tricholaenae	1: 222
Rhynchosia	Uromyces rhynchosiae	4: 270
Rhynchospora	Puccinia nabugoboensis	2: 59
Ricinus	Melampsora euphorbiae	4: 243
Rubia	Puccinia rubiicola	5: 531
Rubus	Hamaspora engleriana	4: 241
	Hamaspora longissima	4: 242
Ruella	Puccinia ruelliae	5: 532
Rumex	Puccinia obscuripora	4: 252
Saccharum	Puccinia melanocephala	1: 223
Sanicula	Puccinia saniculae	4: 261
Satureja	Puccinia menthae	5: 530
Schizachyrium	Uromyces clignyi	1: 228
Securinega	Aecidium fluggeae	4: 239
Senecio	Aecidium dubiosum	5: 509
	Puccinia hansfordiana	5: 524
	Puccinia hedbergii	5: 524
Setaria	Phakopsora setariae	1: 211
	Uromyces setariae-italicae	1: 232
Sida	Puccinia heterospora	4: 250
Smilax	Puccinia smilacis-kraussianae	3: 67
Sorghum	Puccinia nakanishikii	1: 223
Spermacoce	Puccinia lateritia	5: 528
Spergula	Puccinia arenariae	4: 247
Spilanthes	Puccinia africana	5: 518
Sporobolus	Uredo kabaleensis	1: 227
	Uredo sporoboli-pyramidalidis	1: 227
	Uromyces tenuicutis	1: 233
Stylosanthes	Uredo stylosanthis	4: 265
Tephrosia	Ravenelia tephrosiae	4: 264
Tetradenia	Puccinia tetradeniae	5: 535
Thalictrum	Uromyces wiehei	4: 271
Themeda	Phakopsora incompleta	1: 210
	Uromyces clignyi	1: 228
Thunbergia	Puccinia thunbergiae	5: 535
Tragia	Puccinia tragiae	4: 262
Tristemma	Puccinia necopina	5: 530
Valeriana	Uromyces sasaënsis	5: 542
Vangueria	Hemileia woodii	5: 516

Vernonia	Aecidium vernoniae-podocomae	5: 513
	Phakopsora vernoniae	5: 516
	Puccinia vernoniicola	5: 536
Vigna	Phakopsora pachyrhizi	4: 244
	Uromyces vignae	4: 270
Viola	Puccinia violae	4: 262
Wissadula	Puccinia abutili	4: 245
Xyris	Uredo xyridis	3: 68
Zea	Puccinia polysora	1: 224
	Puccinia sorghi	1: 226
Zehnera	Puccinia cephalandrae	5: 520
Zornia	Puccinia zorniae	4: 262

References

Ahmad, S. 1956. Uredinales of West Pakistan. Biologia 2: 26-101.

Arthur, J.C. 1934. Manual of the rusts in United States and Canada. Purdue Res. Foundation, Lafayette, Indiana.

Bisby, G.B. & Wiehe, P.O. 1953. The rusts of Nyasaland. Mycol. Pap. No. 54.

Bouriquet, G. & Bassino, J.-P. 1965. Les Urédinées de Madagascar. Prodrome fl. mycol. Madagascar. V.

Cooke, M.C. 1882. Exotic fungi. Grevillea 10(1881-82): 121-130.

Cummins, G.B. 1945. Descriptions of tropical rusts - VII. Bull. Torrey Bot. Club 72: 205-222.

- 1952. Uredinales from various regions. Bull. Torrey Bot. Club 79: 212-234.

Dale, W.T. 1955. New species of Uredinales from Trinidad. Mycol. Pap. No. 59.

Doidge, E.M. 1926. A preliminary study of the South African rust fungi. Bothalia 2: 1-228.

- 1948. South African rust fungi. Part V. Bothalia 4: 895-918, 1948.

Ebbels, D.L. 1972. Additions to the mycoflora of south-western Uganda. J. E. Africa nat. Hist. Soc. Nat. Mus. No. 133.

- & Allen, D.J. 1979. A supplementary and annotated list of plant diseases, pathogens and associated fungi in Tanzania. Phytopath. Pap. No. 22.

Eboh, D.O. 1977. Aecidium mitracarpi Syd., a synonym of Puccinia bakoyana Pat. & Har. Trans. Br. mycol. Soc. 69: 136-137.

Gilli, A. 1972. Ein kleiner Beitrag zur Pilzflora von Tanganyika. Sydowia 25 (1971): 128-129.

Gjærum, H.B. 1983. East African rusts (Uredinales), mainly from Uganda. 1. On Poaceae. Mycotaxon 18: 209-234.

- 1984. 2. On Cyperaceae. Mycotaxon 20: 53-63.
- 1984a. 3. On Amaryllidaceae, Commelinaceae, Iridaceae, Juncaceae, Liliaceae, Orchidaceae and Xyridaceae. Mycotaxon 20: 65-72.
- 1985. 4. On families belonging to Apetalae and Polypetalae. Mycotaxon 24: 237-273.
- 1986. Rust fungi (Uredinales) from Cape Verde Islands. Bot. Macar. 12-13(1984): 123-138.

Henderson, D.M. 1970. Rust from East Africa. Notes R. Bot. Gdn Edinb. 30: 395-407.

- 1972. Rust fungi from East Africa: II. Notes R. Bot. Gdn Edinb. 31: 441-446.

Hughes, S.J. 1952. Fungi from the Gold Coast - I. Mycol. Pap. No. 48.

Hylander, N., Jørstad, I. & Nannfeldt, J.A. 1953. Enumeratio uredinearum scandinavicarum. Opera Botanica, 1,1: 1-2.

Jørstad, I. 1956. Reliquiae Lagerheimianae. African Uredinales. Ark. Bot., Ser. 2, B. 3 nr 17: 563-598.

Laundon, G.F. 1963. Rust fungi 1: On Acanthaceae. Mycol. Pap. No. 89.

Majewski, T. & Nowak, K.A. 1982. Les champignons parasites récoltés au Rwanda. Bull. Soc. Myc. Fr. 98: 369-375.

Mayor, E. 1964. A propos de trois Urédinales du Sénégal. Bull. Soc. Mycol. Fr. 80: 328-339.

Mogh, M. & Hindorf, H. 1971. Parasitic fungi collected in Kenya. Nova Hedwigia 21: 479-504.

Nattrass, R.M. 1961. Host list of Kenya fungi and bacteria. Mycol. Pap. No. 81.

Nevodovsky, G.S. 1956. Flora sporovykh rastenii Kazakhstana. Rzhavtchinnye griby. Alma-Ata.

Petrak, F. 1959. Ein kleiner Beitrag zur Pilzflora von Tanganyika. Sydowia 13: 223-234.

Stewart, R.B. & Yirgou, D. 1867. Index of plant diseases in Ethiopia. Exp. Sta. Bull. No. 30, Coll. Agric., Haille Selassie I Univ.

Sydow, P. & H. 1924. Monographia Uredinearum IV. Uredineae imperfectae. Lipsiae.

Viennot-Bourgin, G. 1953. Urédinales d'Afrique (3e note). Urédinales de Côte d'Ivoire (2e note). Uredineana 4: 125-228.

- 1958. Urédinales d'Afrique (5e note). Urédinales de Côte d'Ivoire (4e note). Uredineana 5: 137-248.

Wakefield, E.M. 1920. Fungi exotici: XXV. Notes on Uganda fungi. Bull. Misc. Inf. R. Bot. Gdns Kew No. 9: 289-300.

- & Hansford, C.G. 1949. Contribution towards the fungus flora of Uganda. IX. The Uredinales of Uganda. Proc. Linn. Soc. Lond., Sess. 161, 1948-49, pt. 2: 162-198.

Yen, J.-M. 1970. Etude sur les Champignons parasites du Sud-Est asiatique. XIII: Quelques espèces d'Urédinées de Malaisie. Revue Mycol. 34: 299-339.

Erratum

In No. 3 of this series of papers on East African rusts (Mycotaxon 20: 65-72, 1984) on p. 68 Asparagus officinalis L. is given as a host for Uredo kabanyoloensis Gj. The host should be A. plumosus Baker.

ERRATA, VOLUME TWENTY-SEVEN

Page	558	line	2	*for*	11x	*read*	10x
			3	*for*	18x	*read*	16x
	559		2&3	*for*	11x	*read*	10x
	560		2	*for*	300x	*read*	264x
			4	*for*	600x	*read*	528x
	561		4	*for*	660x	*read*	580x
			5	*for*	1100x	*read*	970x

MYCOTAXON

Vol. XXVII, pp. 551-554 October-December 1986

CONFIRMATION OF ASCOSPHAERA APIS IN GEORGIA

R. T. Hanlin and R. A. Saunders

Department of Plant Pathology
University of Georgia
Athens, Georgia 30602

ABSTRACT

Ascosphaera apis, cause of chalk brood disease of bees, is described from honey bee larvae in Georgia for the first time. Although this is the first published report of the disease in the state, it apparently has been known to bee keepers since the 1920's.

Keywords: *Apis mellifera*, honey bee, insect mycosis.

INTRODUCTION

Chalk brood of bees, caused by *Ascosphaera apis* (Maassen ex Claussen) Olive & Spiltoir, can be a serious disease of domesticated honey bees (Bailey 1981). During the past few years several publications (Hitchcock and Christensen 1972; Thomas and Luce 1972; Christensen and Gilliam, 1983; Rose et al. 1984) have described collections of honey bees (*Apis mellifera* L.), infected with chalk brood disease from various areas of the United States. Georgia is not among the areas listed, nor is the fungus included in published lists of Georgia ascomycetes (Miller 1941; Hanlin 1963). A search of the literature also failed to yield any references to the fungus in Georgia. A mail survey of bee inspectors in the United States, however, revealed that the disease is present in Georgia and 32 other states (Menapace and Wilson 1976). The purpose of this paper is to confirm the occurrence and identity of *A. apis* in Georgia.

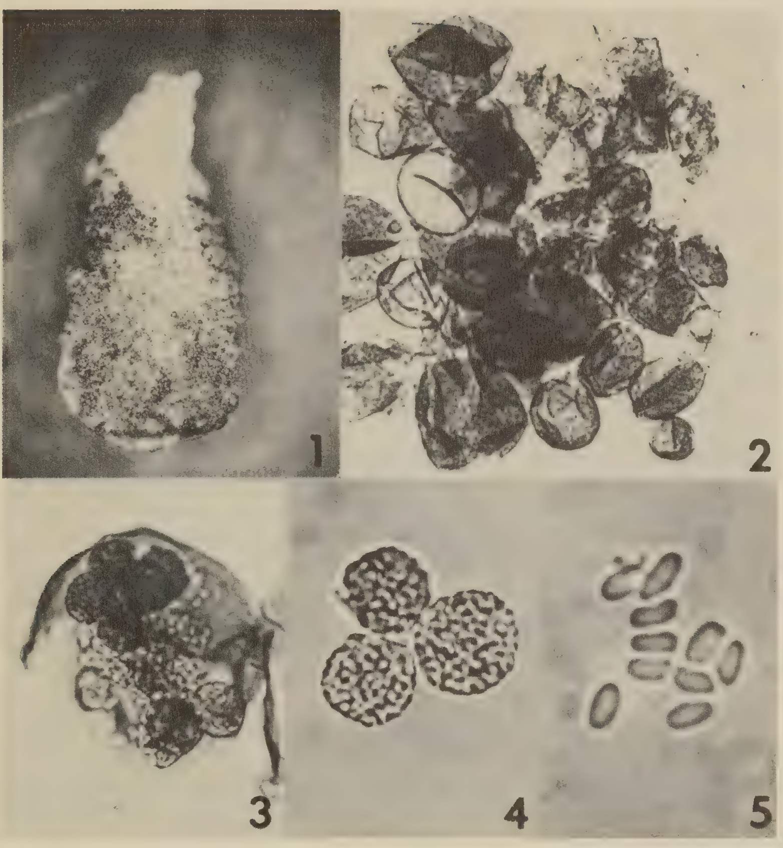
OBSERVATIONS AND DISCUSSION

In April, 1986, specimens of diseased honey bee larvae were collected from a hive in Madison County, Georgia and taken to the laboratory for examination. The larvae were covered with a dense layer of hyphae and brown spheres (Fig. 1). Examination of these structures revealed that they were spore cysts [(54)-75-(110)µm diam](Fig. 2) containing spore balls [(12)-16-(26)µm diam](Fig. 3). The spore balls (Fig. 4) were composed of large numbers of hyaline, one-celled, ellipsoidal spores [(3.2)-3.5-(4.0) X (1.6)-1.9-(2.0)µm](Fig. 5) that were straight to slightly curved, with rounded ends. On the basis of these characteristics, the fungus was identified as *Ascosphaera apis* (Rose et al. 1984).

The first report of chalk brood in the United States was on wild bees collected in Utah in 1965 (Baker and Torchio 1968). The disease was first found on honey bees in Tehama County, California in 1968 (Thomas and Poinar 1973), and it was found in numerous other counties in subsequent years (Thomas and Luce 1972). By 1975 the disease had been recorded in 33 of the 48 contiguous states. Whether the disease spread rapidly or had simply gone unreported is unknown, but the latter seems likely. In Georgia, e.g., bee keepers reported seeing the disease in the 1920's (Menapace and Wilson 1976), forty years before its 'discovery' in the United States, yet there appears to be no record of its occurrence in the literature. This emphasizes the importance of publishing distribution records of fungi, especially those of economic importance. As of 1975 the disease was still unrecorded from Louisiana, Mississippi, South Carolina and Tennessee in the southeastern United States, but it is probable that it has either been overlooked or ignored.

ACKNOWLEDGEMENT

We thank Martha Christensen and Rodney Roberts for review of the manuscript.



Figures 1-5. *Ascosphaera apis*. Fig. 1. Honey bee larva covered with spore cysts. X12. Fig. 2. Spore cysts from bee larva. X256. Fig. 3. Broken spore cyst with spore balls. X729. Fig. 4. Spore balls. X1450. Fig. 5. Ascospores. X3500.

LITERATURE CITED

Bailey, L. 1981. *Honey Bee Pathology.* Academic Press, New York.

Baker, G. M., and P. F. Torchio. 1968. New records of *Ascosphaera apis* from North America. *Mycologia* 60: 189-190.

Christensen, M., and M. Gilliam. 1983. Notes on the *Ascosphaera* species inciting chalkbrood in honey bees. *Apidologie* 14: 291-297.

Hanlin, R. T. 1963. A revision of the Ascomycetes of Georgia. *Univ. Georgia Coll. Agric. Mimeo. Ser. N. S.* 175: 1-68.

Hitchcock, J. D., and M. Christensen. 1972. Chalk brood disease of honey bees in the United States. *Amer. Bee J.* 112: 248-249, 254.

Menapace, D., and W. T. Wilson. 1976. The spread of chalk brood in the North American honey bee, *Apis mellifera*. *Amer. Bee J.* 116: 570-573.

Miller, J. H. 1941. The Ascomycetes of Georgia. *Plt. Dis. Reptr. Suppl.* 131: 31-93.

Rose, J. B., M. Christensen, and W. T. Wilson. 1984. *Ascosphaera* species inciting chalkbrood in North America and a taxonomic key. *Mycotaxon* 19: 41-55.

Thomas, G. M., and A. Luce. 1972. An epizootic of chalk brood, *Ascosphaera apis* (Massen [sic] ex Claussen) Olive and Spiltoir, in the honey bee, *Apis mellifera* L. in California. *Amer. Bee J.* 112: 88-90.

Thomas, G. M., and G. O. Poinar, Jr. 1973. Report of diagnosis of diseased insects, 1962-1972. *Hilgardia* 42: 261-359.

MYCOTAXON

Vol. XXVII, pp. 555-562 October-December 1986

RÉCOLTES DE BISCOGNIAUXIA DENNISII (PYRENOMYCETES, ASCOMYCETES) DANS LE SUD-OUEST DE LA FRANCE

FRANÇOISE CANDOUSSAU *

22, rue Hoô-Paris
64000 Pau, France

Résumé: Biscogniauxia dennisii, connue jusqu'à présent de deux stations en Tchécoslovaquie sur Acer et Ulmus, est une espèce assez fréquente sur Quercus dans trois départements du Sud-Ouest de la France. Cette espèce n'ayant pas été illustrée dans la littérature, il nous a semblé utile de le faire à l'aide des photos. Une description d'après la récolte d'Amou (Landes) et une discussion sur le genre Biscogniauxia sont faites.

Summary:Biscogniauxia dennisii, which has been reported from two locations in Czekoslovakia on Acer and Ulmus is frequently encountered on Quercus in three departments in Southwest France. This species has not been illustrated in the literature. It seemed useful to present photographs of material. A description based on a collection from Amou (Landes) and a discussion of the genus Biscogniauxia is presented.

---

* Correspondante scientifique de l'herbier de pathologie végétale de l'Université de Cornell, Ithaca, N. Y. 14853.

Biscogniauxia dennisii (Z. Pouzar) Z. Pouzar, Ceská Mykologie 33:216. 1979

Basionym: Nummularia dennisii Z. Pouzar, Kew Bull. 31: 653. 1976

Stromas crateriformes, erumpents, enfoncés dans l'écorce du bois, circulaires à elliptiques, le plus souvent légèrement concaves, 5 - 18 x 4 - 8 mm de large et 3 - 4 mm d'épaisseur. Marge lisse, surélevée, noire, plus ou moins régulière, ostioles proéminentes papillées (Figs. 1, 3). Les stromas en coupe font apparaître les périthèces monostiques noirs et brillants, allongés cylindriques, remplissant de bas en haut presque toute la hauteur du stroma, et mesurant jusqu'à 3 mm de haut et 0.5 à 1 mm de large (Figs. 2, 4). La base plus claire du stroma consiste en matières décomposées du bois du support mélangées aux hyphes du pyrenomycète (Fig. 2). **Ectostroma** délimité par une couche mince carbonacée. **Asques** 110 - 150 x 14 - 16 µm courtement stipités, (Figs. 5, 6), appareil apical distinctement amyloide (Figs. 7, 8). **Ascospores** huit, unisériées, lisses, brun foncé, opaques sous le microscope, largement ellipsoides à citriformes, 14.5 - 18 x 11 - 15 µm, la plupart avec bulles de "De Bary" et sillon germinal visible droit ou légèrement en spirale (Fig. 7). **Paraphyses** cylindriques simples, septées, plus longues que les asques, 3.5 - 5 µm de large (Figs. 5, 6).

Récoltes examinées: FRANCE: 13.II. 1971 - sur Quercus pedunculata, Bois de Saint Maur, 32 Mirande, Gers, F. Candoussau. XI. 1974 - sur Quercus pedunculata, Pouylebon, 32 Mirande, Gers, F. Candoussau. 20. II. 1983 - sur Quercus pedunculata, Bois de Garlin (35 km Nord de Pau), Pyrénées Atlantiques, F. Candoussau, J. Vivant, G. Gilles. 2.III. 1986 - sur Quercus pedunculata, Bois d'Amou, Landes, F. Candoussau & G. Gilles.

Notre récolte concorde bien avec la description de la récolte type de Pouzar (1976). Les stromas étant d'une grandeur très variable (Pouzar,1986) nous ne nous attarderons pas sur les dimensions plus petites de celles de nos récoltes.
Jusqu'à présent cette espèce a été signalée sur Acer (Slovaquie; Pouzar, 1976) et sur Ulmus (Bratislava; Pouzar, 1986). Dans le

Sud Ouest de la France, depuis 1971 (récoltes mal identifiées) nous ne l'avons récoltée que sur Quercus et elle ne semble pas rare comme en Tchécoslovaquie où deux stations sont seulement connues. La France et la Tchécoslovaquie sont les deux seuls pays cités jusqu'à présent dans la littérature pour sa répartition géographique.

Le genre Biscogniauxia O. Kuntze a été émendé par Pouzar en 1979 pour remplacer le genre Nummularia Tul., invalide, car préoccupé par un genre d'Angiosperme (Nummularia Hill; Pouzar, 1979).

D'abord, Miller (1928) a rejeté la séparation du genre Nummularia d'avec le genre Hypoxylon Bull., mais plus tard il a émendé le genre Nummularia et y a versé les espèces cupulées, choisissant N. discreta (Schw.) Tul. comme lectotype du genre (Miller, 1932).

D'autres auteurs ont suivi, considérant ces espèces distinctes et différentes du genre Hypoxylon (Jong & Benjamin, 1971). Eckblad & Granmo (1978) ont crée Nummulariella Eckblad & Granmo pour les espèces cupulées et Pouzar (1979) en émendant l'ancien genre Biscogniauxia a réuni sous ce nom les espèces cupulées et applaties.

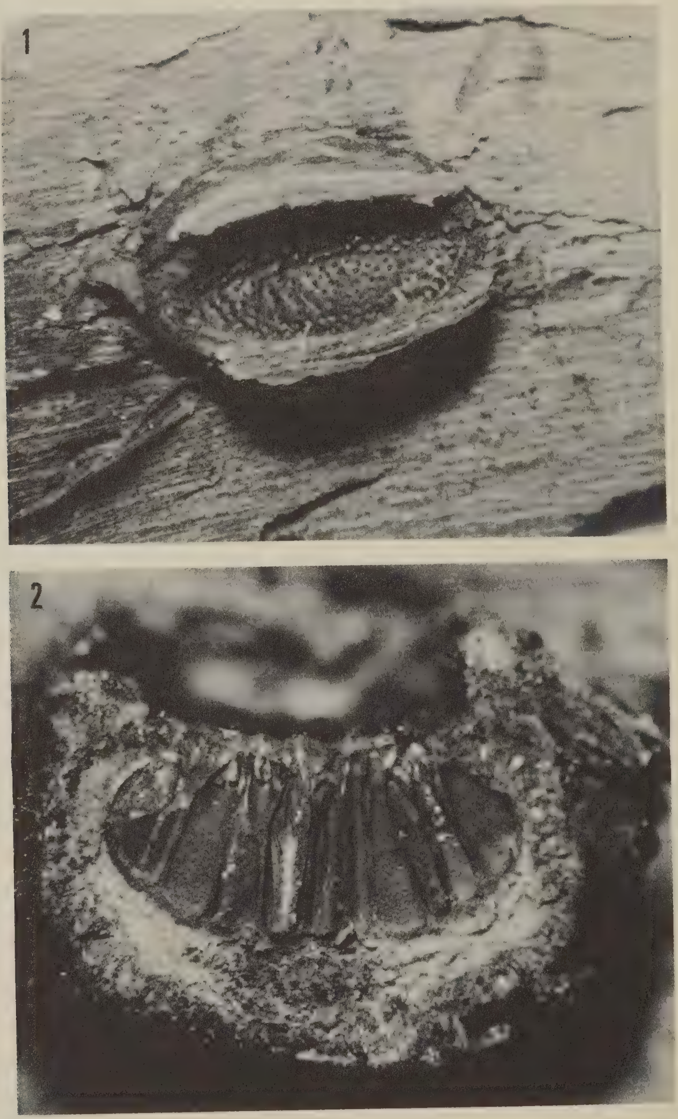
Les espèces du genre Biscogniauxia sont caractérisées macroscopiquement par des stromas cupulés et des périthèces se développant dans la base de l'entostroma et atteignant la surface du stroma par des ostioles plus ou moins allongées, alors que dans le genre Hypoxylon les périthèces sont situés dans la partie supérieure de l'entostroma, de plus la base du stroma se mélange aux matières décomposées de la plante.

Microscopiquement l'absence d'exospore hyaline des spores, l'absence de pigment clair soluble dans le KOH, le foramen plat des asques et l'appareil apical de l'asque, amyloide d'une manière diffuse, caractérisent les espèces de ce genre.

Récemment Callan & Rogers (1986), après avoir cultivé Biscogniauxia marginata (Fr.) Z. Pouzar, B. dennisii et B. repanda (Fr.) O. Kuntze ont constaté que l'anamorph était un Nodulisporium comme dans beaucoup d'autres espèces du genre Hypoxylon et sont arrivés à la conclusion que les deux genres doivent être très proches.

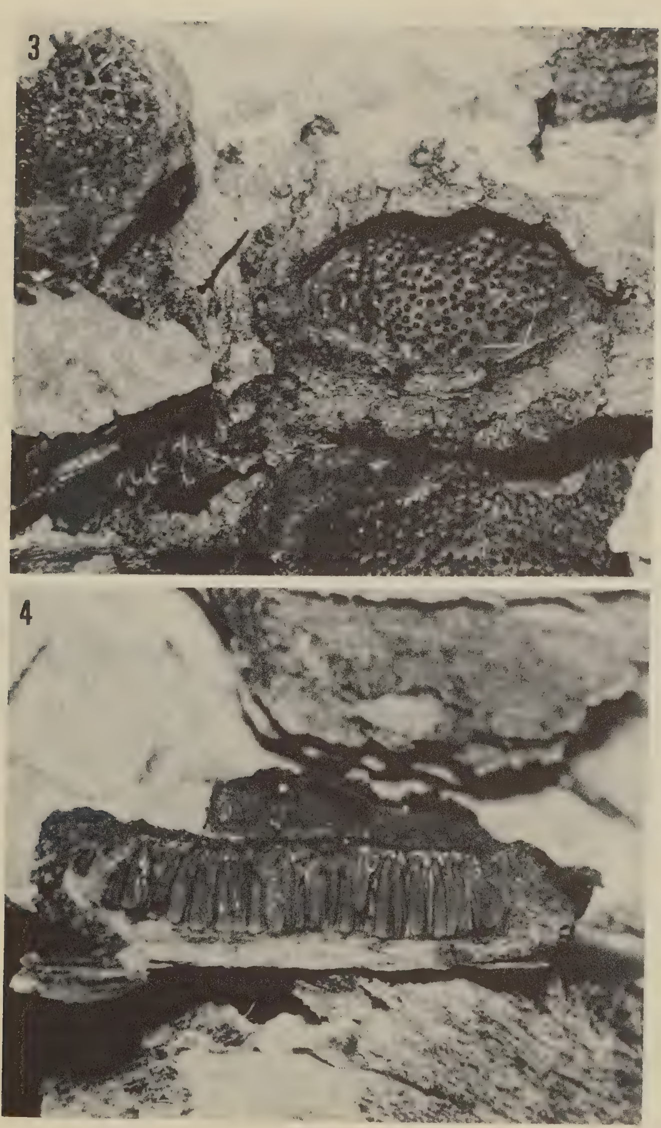
Toutefois les genres Biscogniauxia et Hypoxylon sont deux genres bien différents et se distinguent particulièrement par l'ontogénie de leur stroma.

SEE ERRATA

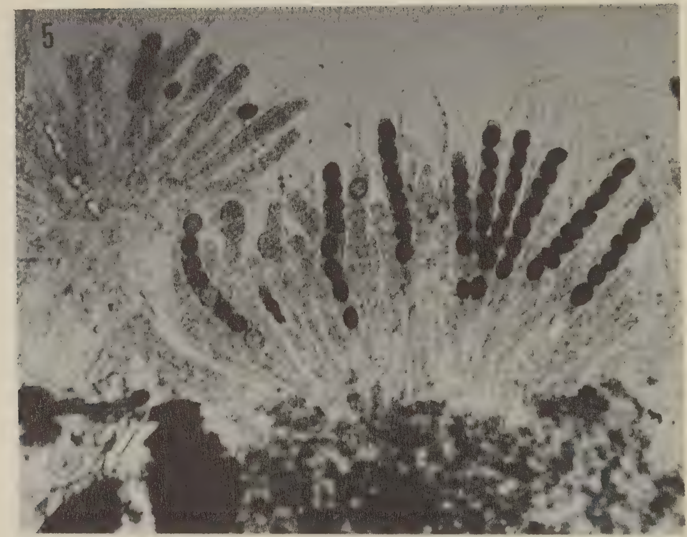


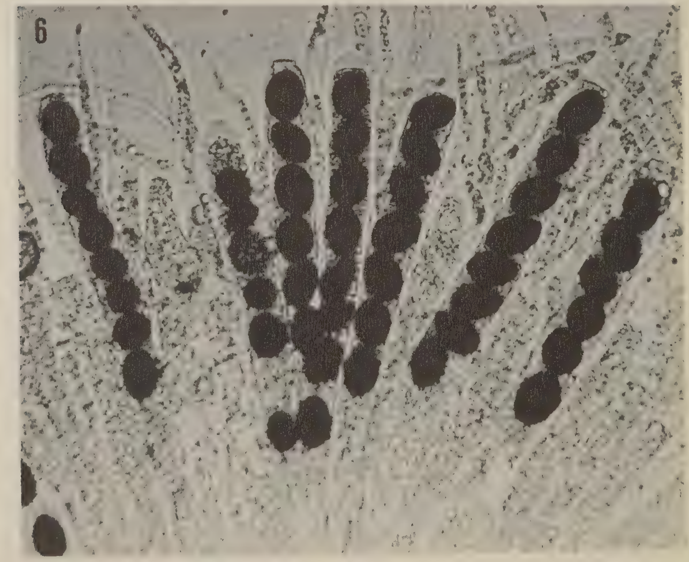
Figs. 1 - 2. *Biscogniauxia dennisii.* - Fig. 1. Stroma sur bois décortiqué légèrement concave; 11x. - Fig. 2. même stroma, en coupe faisant apparaître les périthèces monostiques; 18x.

SEE ERRATA



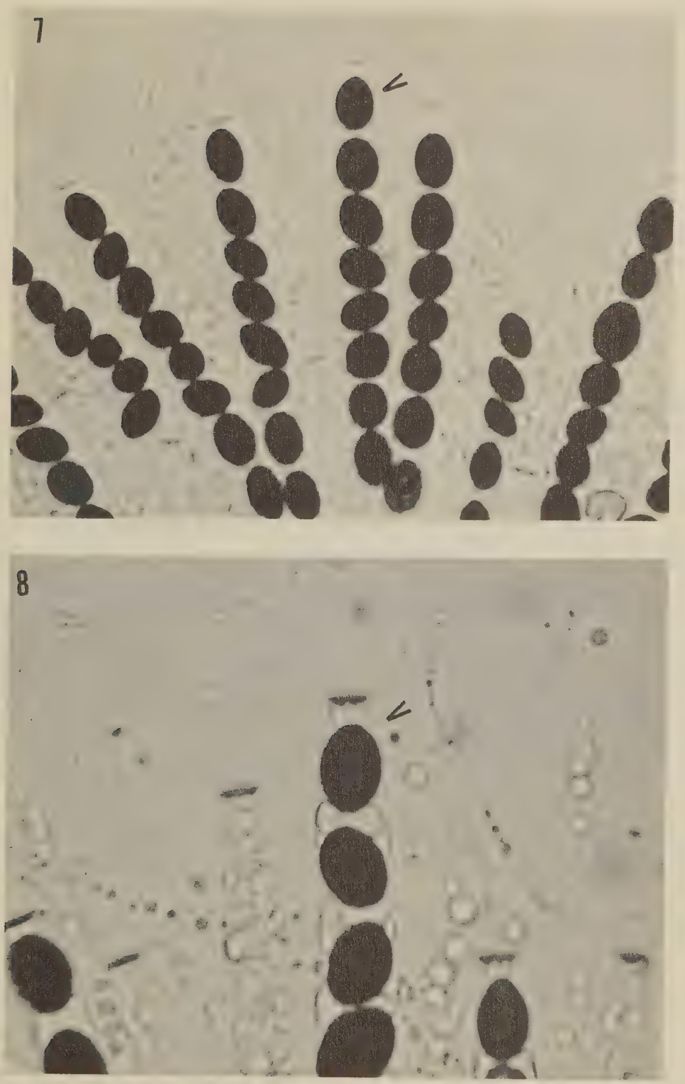
Figs. 3 - 4. Biscogniauxia dennisii. - Fig. 3. Stroma étalé sur bois non écorcé; 11x. - Fig. 4. même stroma faisant apparaître les périthèces monostiques; 11x.





Figs. 5 - 6. Biscogniauxia dennisii. - Fig. 5. Préparation dans l'eau. Asques, ascospores et paraphyses; 300x. - Fig. 6. Détail de la même préparation mettant en évidence la structure apicale des asques; 600x.

SB ERRATA



Figs. 7 - 8. Biscogniauxia dennisii. - Fig. 7. Préparation dans le Melzer avec réaction positive de l'appareil apical des asques, sillon germinal visible sur une ascospore, certaines avec bulles de "de Bary"; 660x. - Fig. 8. Détail de la même préparation; 1100x.

Remerciements

Nous remercions Bruno Erb (Erlinsbach, SUISSE) pour les photographies, le Dr. L. Petrini (Zürich, SUISSE) pour son aide bibliographique et ses commentaires. Toute notre reconnaissance au Professeur J. D. Rogers (Washington State University, Pullman, Wa., U.S.A.) pour l'identification de notre récolte (Garlin 1983) et pour la révision de notre manuscrit.

Bibliographie

Callan, B. E. & J. D. Rogers (1986). Cultural characters and anamorphs of *Biscogniauxia* (= *Nummularia*) *marginata*, *B*. *dennisii* and *B*. *repanda*. Can. J. Bot. 64: 842 - 847.

Eckblad, F. E. & A. Granmo (1978). The genus *Nummularia* (Ascomycetes) in Norway. Norw. J. Bot. 25: 69 - 75.

Jong, S. C. & C. R. Benjamin (1971). North American species of *Nummularia*. Mycologia 63: 862 - 876.

Miller, J. H. (1928). Biologic studies in the Sphaeriales II. Mycologia 20: 205 - 339.

Miller, J. H. (1932). British Xylariaceae II. Trans. Br. mycol. Soc. 17: 125 - 135.

Pouzar, Z. (1976). *Nummularia* *dennisii*, a new species of Xylariaceae from Central Europe. Kew Bull. 31: 653 - 655.

Pouzar, Z. (1979). Notes on taxonomy and nomenclature of *Nummularia* (Pyrenomycetes). Ceská Mycologie 33: 207 - 219.

Pouzar, Z. (1986). A key and conspectus of Central European species of *Biscogniauxia* and *Obolarina* (Pyrenomycetes). Ceská Mycologie 40: 1 - 10.

MYCOTAXON

Vol. XXVII, pp. 563-610 October-December 1986

NEW SPECIES OF THE LICHEN GENUS XANTHOPARMELIA FROM SOUTHERN AFRICA (ASCOMYCOTINA: PARMELIACEAE)*

Mason E. Hale, Jr.

Department of Botany, Smithsonian Institution
Washington, DC 20560, U.S.A.

Abstract. Sixty-two new species of Xanthoparmelia are described from southern Africa: X. acrita Knox & Hale, X. africana Hale, X. aliphatica Hale, X. barklyensis Hale, X. calvinia Hale, X. capensis Hale, X. ceresensis Hale, X. competita Hale, X. crassilobata Hale, X. denudata Hale, X. diacida Hale, X. duplicata Hale, X. effigurata Hale, X. endochromatica Hale, X. enteroxantha Hale, X. epigaea Hale, X. equalis Hale, X. esterhuyseniae Hale, X. evernica Hale, X. globisidiosa Hale, X. gyrophorica Hale, X. hybrida Hale, X. indumenica Hale, X. karooensis Hale, X. lagunebergensis Hale, X. lesothoensis Hale, X. lividica Hale, X. lobulifera Hale, X. minuta Knox & Hale, X. mollis Hale, X. namakwa Hale, X. namaquensis Hale, X. neosynestia Hale, X. neotasmanica Hale, X. nuwarensis Hale, X. ochropulchra Hale, X. olifantensis Hale, X. olivetorica Hale, X. oribensis Hale, X. probarbellata Hale, X. pustulifera Hale, Nash & Elix, X. rubromedulla Hale, X. saniensis Hale, X. serusiauxii Hale, X. simulans Hale, X. skyrinifera Hale, X. stenosporonica Hale, X. subcolorata Hale, X. subcrustosa Hale, X. subnigra Hale, X. subochracea Hale, X. subruginosa Hale, X. surrogata Hale, X. tablensis Hale, Nash & Elix, X. terricola Hale, Nash & Elix, X. thamnolica Hale, X. toninioides Hale, X. transvaalensis Hale, Nash & Elix, X. treurensis Hale, Nash & Elix, X. tumidosa Hale, X. viridis Hale, and X. wesselsii Hale. Two new combinations are also made: X. ianthina (Brusse) Hale and X. lecanoracea (Mull. Arg.) Hale.

---

*This work was supported by a grant from the Scholarly Studies Program, Smithsonian Institution. I would like to thank Dirk Wessels, University of the North, Pietersburg, for arranging forays in S.W.A./Namibia, eastern Transvaal and the Cape Town area for the International Association for Lichenology, making possible collecting in areas not previously visited by lichenologists. I am especially indebted to Anita Johnson and Dr. C. F. Culberson for determining the chemistry of several critical species. Dr. J. A. Elix, Dr. David Knox, Dr. T. H. Nash and Jen Johnston contributed specimens and/or information on nine of the species included here and valuable loans were received from Dr. Ove Almborn (LD), Frank Brusse (PRE) and Dr. Harrie Sipman (B).

Xanthoparmelia acrita Knox and Hale, sp. nov. Fig. 1

Thallus laxe adnatus, terricola vel saxicola, 5-8 cm latus, lobis sublinearibus, 1-2 mm latis, superne plus minusve maculatus, isidiis sorediisque destitutus, subtus subconvolutus, pallide brunneus, dense rhizinosus.

Thallus loosely adnate on rocks, soil, pebbles or soil over rocks, 5-8 cm broad, somewhat darkish greenish yellow; lobes sublinear, quite variable, 1-2 mm wide, separate to subimbricate, subdivaricately branched; upper surface weakly to moderately maculate, shiny; isidia and soredia absent; lower surface weakly to distinctly convolute, without a distinct paler rim below along the margins, pale brown, moderately to densely rhizinate, the rhizines fine, brown or blackening, especially at lobe tips, 0.5-1 mm long, simple to furcate.

Pycnidia rare; conidia bifusiform, 0.5 X 5-6 µm. Apothecia rare, adnate to substipitate, 2-5 mm in diameter; hymenium 45-48 µm; spores poorly developed, 6 X 9 µm.

Chemistry: Fumarprotocetraric and usnic acids, with or without succinprotocetraric acid (both present in holotype).

Type collection: On soil among low sandstone ledges in Fynbos, Ceres Nature Reserve at Michells Pass, about 1.5 km SW of Ceres on Hwy R46, elev. ca 600 m, Cape Province, S. Africa, Grid 3319 AD, M. E. Hale 72031, 24 Jan. 1986 (US, holotype; PRE, isotype).

This species is distinguished by the weakly convoluted lobes and chemistry. It is rather common on open sandstone outcrops and nearby sandy soil in the karoo and Fynbos of southwestern Cape Province. Some specimens contain only fumarprotocetraric acid.

Additional specimens examined. S. Africa. Cape Province: Same locality as the holotype, Hale 72014, 72022, 72024 (US); Karoo Botanical Garden, Worcester, Grid 3319 CC, Hale 74021, 74022, 74024, 74049, 74051, 74052, 74103 (US), Nash 23494 (ASU, US); near Joubertina, Grid 3323 DD, Esterhuysen 16596, 16624 (BOL); Tafelberg, Cedarberg, Grid 3219 AC, Schelpe 1933, 1940 (BOL, US); 32.7 km ESE of Citrusdal, Grid 3219 CA, Hale 72013, 72015, 72021, 72023, 72115 (US); Witteberg, Grid 3318 DB, Leighton 263 (BOL, US); Klein Roggeveldberge, 47 km SW of Sutherland, Grid 3220 DC, Leighton 3150 (BOL, US); Sir Lowry Pass, Grid 3418 BB, Guthrie & Page s.n. (BOL, US); Mountains above Tulbagh Waterfall, Grid 3318 BD, Stephens s.n. (BOL, US); 23 km SW Ladismith, Grid 3321 CA, Hale 74020 (US); Uniondalespoort, Grid 3323 CA, Hale 73003, 73008 (US).

Xanthoparmelia africana Hale, sp. nov. Fig. 2

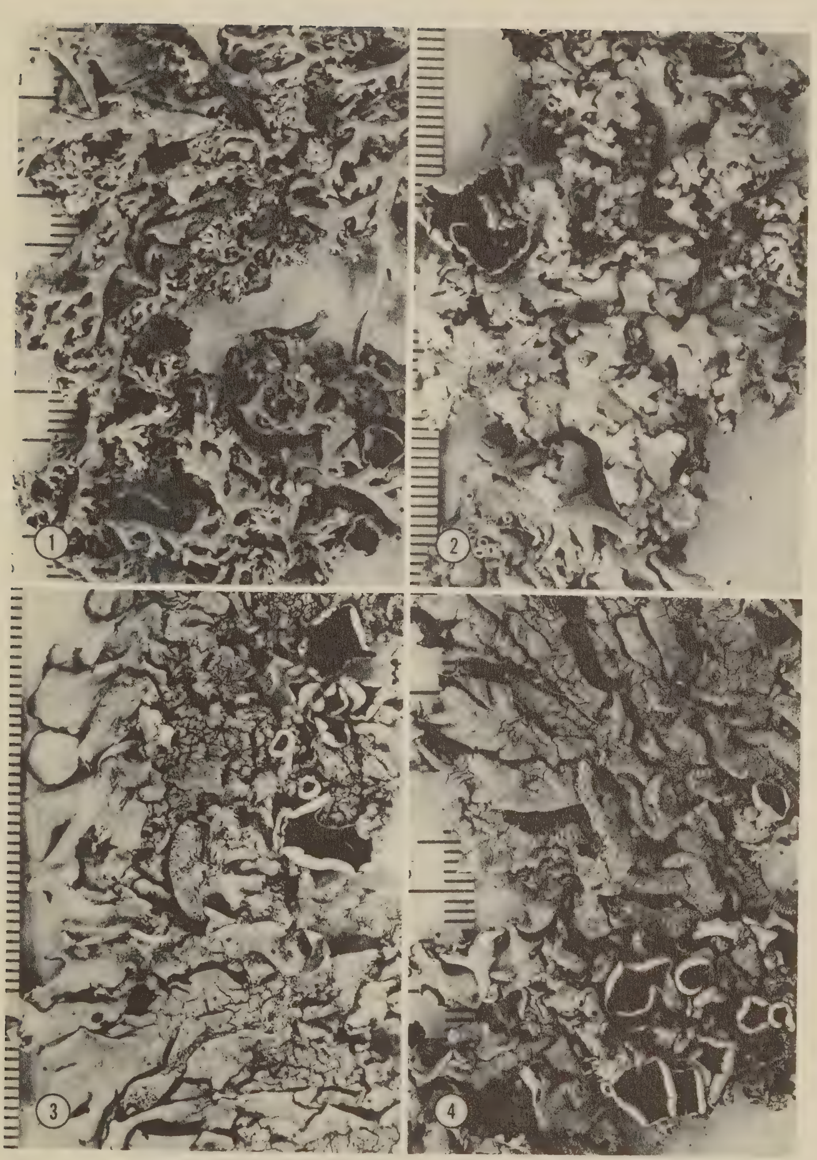
Thallus laxe adnatus, saxicola, 10-20 cm latus, lobis sublinearibus, 1.5-5 mm latis, superne vix maculatus, isidiis sorediisque destitutus, subtus planus, nigricans, dense rhizinosus.

Thallus loosely adnate on rock, firm, sometimes forming thick pulvinate colonies 10-20 or more cm broad, bright yellowish green; lobes sublinear, dichotomously branched, 1.5-5 mm wide, crowded and imbricate; upper surface weakly to rather distinctly white maculate with age; isidia and soredia absent; lower surface plane, black at the center with a broad brown zone at the margins, densely rhizinate, the rhizines initially brown but soon blackening, 0.5-1.5 mm long, simple to furcate.

Pycnidia well developed; conidia bifusiform, 0.5 X 6-8 µm. Apothecia well developed, subpedicellate, 5-10 mm in diameter; hymenium 42-45 µm; spores 6-7 X 9-12 µm.

Chemistry: Salazinic and usnic acids.

Type collection: Sirimon Track, Mt. Kenya, elev. 3300-3400 m, Kenya,



Figures 1-4. Holotypes of Xanthoparmelia: 1, X. acrita; 2, X. africana; 3, X. aliphatica; 4, X. barklyensis. Scale = mm.

F. R. Fosberg and O. M. Mwangangi 49919, 18 March 1968 (US, holotype; PRE, isotype).

This conspicuous lichen is confined to higher elevations in the major mountains in Kenya and Uganda and occurs at 700-800 m elevation in southern and eastern Cape Province. I had originally identified the material as X. tasmanica (Hook. & Tayl.) Hale, a widespread lichen in Australasia, southern Africa and the Americas, which has no maculae, a more membranous thallus and sparse to moderate rhizines.

Additional specimens examined. Kenya: Mt. Elgon, Hedberg 933c (UPS, US); Mt. Kenya, Griffin 28976 (TRT, US), Hedberg 1714 (UPS, US), Schelpe 2659 (BM, US). Tanzania: Kilimanajaro, Hedberg 1393 (UPS, US), Pocs 6934 (US; also issued in Vězda, Lich. Sel. Exs. 1441), Turrall s.n. (BM, US). Uganda. Distr. Bugisu: Mt. Elgon, Manum 12/1967 (BM, US). S. Africa. Cape Province: Meiringspoort, Grid 3322 BC, Hale 73141 (US); 33.8 km W of Dordrecht, Grid 3126 BC, Hale 73140 (US).

Xanthoparmelia aliphatica Hale, sp. nov. Fig. 3

Thallus laxe adnatus, saxicola, 10-12 cm latus, lobis subirregularibus, 3-6 mm latis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, niger, dense rhizinosus.

Thallus loosely adnate on rock, 10-12 cm broad, yellowish green; lobes subirregular, apically subrotund, 3-6 mm wide, contiguous to imbricate; upper surface continuous, emaculate, rugose and cracked with age; isidia and soredia absent; lower surface plane, black, densely rhizinate, the rhizines simple, 0.5-1 mm long.

Pycnidia numerous; conidia bifusiform, 0.5 X 5-7 µm. Apothecia numerous, adnate, 5-8 mm in diameter; hymenium 42-45 µm; spores 5-7 X 10-12 µm.

Chemistry: Constipatic and associated fatty acids, usnic acid.

Type collection: Exfoliating granitic outcrops in karoo, 78.6 km S of Sutherland on Hwy R354, elev. ca 900 m, Cape Province, S. Africa, Grid 3220 DC, M. E. Hale 73107, 29 Jan. 1986 (US, holotype; PRE, isotype).

This large, conspicuous lichen has a black lower surface, a rare trait in fatty acid-containing species shared only by X. subnigra Hale and X. transvaalensis Hale, Nash & Elix (below). It is otherwise similar to X. barklyensis Hale, also described below and occurring with it at the type locality, which differs in having a pale brown lower surface.

Additional specimens examined. S. Africa. Cape Province: Same locality as the holotype, Hale 73125 (US); 40 km E of Sutherland, Grid 3221 AC, Brusse 3336 (PRE).

Xanthoparmelia barklyensis Hale, sp. nov. Fig. 4

Thallus laxe adnatus, saxicola, 8-15 cm latus, lobis subirregularibus, 2.5-5 mm latis, centro laciniatis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, pallide brunneus, modice rhizinosus.

Thallus loosely adnate on rock, 8-15 cm broad, bright yellow green; lobes subirregular to sublinear, 2.5-5 mm wide, contiguous to imbricate, the center becoming laciniate; upper surface continuous, shiny, emaculate; isidia and soredia absent; lower surface plane, pale brown, moderately rhizinate, the rhizines pale brown, simple, 0.5-1 mm long.

Pycnidia numerous; conidia bifusiform, 0.5 X 5-6 µm. Apothecia numerous, adnate, 3-5 mm in diameter; hymenium 40-45 µm; spores 5-7 X 9-11 µm.

Chemistry: Constipatic and associated fatty acids, usnic acid.

Type collection: Barkly Pass, about 18 km N of Elliott along Hwy R58, elev. ca 1800 m, Cape Province, S. Africa, Grid 3127 BB, M. E. Hale 73015, 9 Feb. 1986 (US, holotype; PRE, isotype).

This species appears to be a morph of X. aliphatica Hale with a pale brown lower surface, occurring mostly in the eastern Cape Province region and adjacent Orange Free State on Cave sandstone. The only other obvious relative of this large lichen with a pale lower surface is X. subdecipiens (Vain.) Hale, which is adnate to tightly adnate.

Additional specimens examined. S. Africa. Cape Province: Same locality as the holotype, Hale 73001, 73009, 73012, 73013 (US); 78.6 km S of Sutherland, Grid 3220 DC, Hale 73104 (US); Nieuwoudtville, Grid 3119 AC, Hale 72005 (US); NE of Rouxville, Grid 3026 BD, Hale 74001, 74002 (US); 4.1 km NE of Dordrecht, Grid 3127 AC, Hale 73000 (US). Orange Free State: Brandwagrots, Golden Gate National Park, Grid 2828 BC, Hale, 74003 (US); 4.3 km west of junction Hwy 56 and 26, near Ladybrand, Grid 2927 AB, Hale 74048 (US).

Xanthoparmelia calvinia Hale, sp. nov. Fig. 5

Thallus arcte adnatus, saxicola, 4-6 cm latus, lobis subirregularibus, 0.5-2 mm latis, contiguis, superne maculatus, centrum versus valde rugoso-isidiatus, isidiis globosis, eruptentibus, subtus planus, brunneus, modice rhizinosus.

Thallus tightly adnate on rock, 4-6 cm broad, light brownish yellow green; lobes short, subirregular, 0.5-2 mm wide, contiguous; upper surface faintly maculate, shiny, becoming strongly rugose and finally coarsely isidiate at the center, the isidia globose, ca 0.2 mm in diameter and 0.2-0.3 mm high, pustulate and bursting open to reveal a hollow center; lower surface plane, brown to dark brown, moderately rhizinate, the rhizines brown, simple, 0.2-0.4 mm long.

Pycnidia and apothecia lacking.

Chemistry: Three undetermined substances forming gray or brownish spots on the TLC plates after visualization with sulfuric acid (determined by C. F. Culberson and A. Johnson), usnic acid.

Type collection: Low dolerite ridges, Akkerendam Nature Reserve near Calvinia, elev. 1000 m, Cape Province, S. Africa, Grid 3119 BD, M. E. Hale 75103, 29 Jan. 1986 (US, holotype; PRE, isotype).

This unusual lichen has hollow globose isidia not unlike those of X. evernica Hale (below). Chemically it is related to X. competita Hale (below), which lacks isidia. It is known only from eastern Namaqualand.

Xanthoparmelia capensis Hale, sp. nov. Fig. 6

Thallus adnatus, saxicola, 4-6 cm latus, lobis subirregularibus, 1.2-2.0 mm latis, superne emaculatus, isidiatus, isidiis subcylindricis vel globosis, subtus planus, niger, modice rhizinosus.

Thallus adnate on rock, 4-6 cm broad, pale yellowish green; lobes subirregular, short, 1.2-2.0 mm wide, contiguous; upper surface continuous, shiny, emaculate, isidiate, isidia subcylindrical to globose, 0.15-0.2 mm in diameter, 0.4-0.7 mm high, breaking off apically; soredia absent; lower surface plane, black, sparsely to moderately rhizinate, the rhizines black, simple, about 0.5 mm long.

Pycnidia and apothecia lacking.

Chemistry: Salazinic and usnic acids, chalybaeizans unknown.

Type collection: Low sandstone ledges in pasture along road, 27 km E of Swellendam on N2, elev. ca 200 m, Cape Province, S. Africa, Grid

3420 BA, M. E. Hale 74046, 3 Feb. 1986 (US, holotype; PRE, isotype).

This rare species, widely distributed in southern Cape Province, is similar to stictic acid-containing X. conspersa (Ach.) Hale in adnation and lobe configuration but has a different chemistry. Xanthoparmelia australasica Galloway from Australia and New Zealand, another isidiate species with salazinic acid (but without the chalybaeizans unknown), is more loosely adnate and has sublinear lobes.

Additional specimens examined. S. Africa. Cape Province: Road to Bulhoek, Grid 3126 DC, Hale 74100 (US); Paarl Rock, Grid 3318 DB, Hale 73105 (US); 19.9 km NW Kango Caves, Grid 3322 AC, Hale 73123 (US).

Xanthoparmelia ceresensis Hale, sp. nov. Fig. 7

Thallus adnatus, fragilis, saxicola, 5-7 cm latus, lobis sublinearibus, congestis, 0.5-0.7 mm latis, superne continuus vel leviter reticulato-maculatus, isidiis sorediisque destitutus, subtus planus, niger, sparse rhizinosus.

Thallus adnate to loosely adnate on rock and soil over rock, pulvinate, easily breaking apart, 5-7 cm broad, darkish yellow green; lobes sublinear, 0.5-0.7 mm wide, sparsely dichotomously branched, crowded and appressed-imbricate; upper surface continuous or faintly reticulate-maculate and rugose at the tips, shiny; isidia and soredia absent; lower surface plane, black, very sparsely rhizinate, the rhizines black, coarse, 0.3-0.5 mm long.

Pycnidia well developed; conidia bifusiform, 0.5 X 5-7 µm. Apothecia not fully developed; spores not found.

Chemistry: Microphyllinic and normicrophyllinic acids (in equal concentration), 4-O-methylolivetoric acid (trace) and usnic acid (determined by C. F. Culberson and A. Johnson).

Type collection: Low sandstone ledges in Fynbos, Ceres Nature Reserve at Michells Pass, 1.5 km SW of Ceres on Hwy R46, elev. ca 600 m, Cape Province, S. Africa, Grid 3319 AD, M. E. Hale 72,008, 24 Jan. 1986 (US, holotype; PRE, isotype).

This curious species, known only from one locality in Fynbos, forms brittle, somewhat pulvinate colonies. The appressed sublinear lobes and faint reticulate-maculation, as well as the unusual chemistry (first reported occurrence of microphyllinic acid in the genus), are unique.

Xanthoparmelia competita Hale, sp. nov. Fig. 8

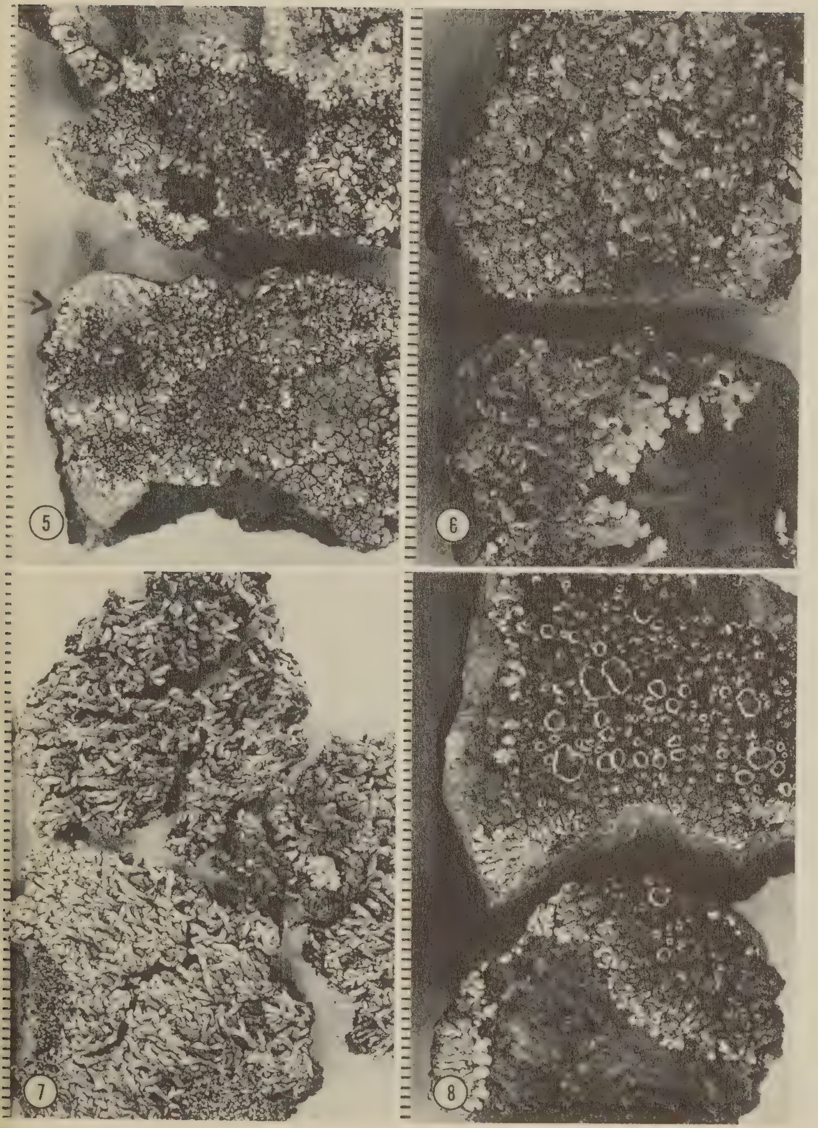
Thallus arcte adnatus, saxicola, 3-6 cm latus, lobis subirregularibus, 0.7-1.5 mm latis, contiguis, superne continuus vel leviter maculatus, centrum versus rugoso-bullatus, subtus planus, pallide brunneus, modice rhizinosus.

Thallus tightly adnate on rock, 3-6 cm broad, dull yellowish green; lobes subirregular, 0.7-1.5 mm wide, short and contiguous; surface continuous to finely reticulately rugose or maculate at the tips, becoming strongly rugose-bullate toward the center, isidia and soredia absent; lower surface plane, pale brown, moderately rhizinate, the rhizines pale brown, simple, 0.2-0.4 mm long.

Pycnidia common; conidia bifusiform, 0.5 X 6-7 µm. Apothecia numerous, adnate, 2-4 mm in diameter; hymenium 33-38 µm; spores 5-6 X 9-10 µm.

Chemistry: The same three undetermined substances occurring in X. calvinia (above), usnic acid (determined by C. F. Culberson and A. Johnson).

Type collection: Large domes of coarse conglomerate in Fynbos, 3.6



Figures 5-8. Holotypes of Xanthoparmelia: 5, X. calvinia; 6, X. capensis; 7, X. ceresensis; 8, X. competita. Scale = mm.

km N of Hwy R62 on Kruisrivier Road, E of Calitzdorp, elev. ca 500 m, Cape Province, S. Africa, Grid 3321 BB, M. E. Hale 73019, 30 Jan. 1986 (US, holotype; PRE, isotype).

This species is closely related to X. calvinia Hale (above) in chemistry. While lobe configuration is similar, X. competita is a brighter yellow and lacks isidia. It appears to be restricted to southern Cape Province.

Additional specimen examined. S. Africa. Cape Province: 24 km N of Willowmore, Grid 3322 AB, Hale 73503 (US).

Xanthoparmelia crassilobata Hale, sp. nov. Fig. 9

Thallus laxe adnatus, terricola, coriaceus, 4-8 cm latus, lobis sublinearibus, 3.5-7 mm latis, superne emaculatus, isidiis sorediisque destitutus, subtus subconvolutus, pallide brunneus, modice rhizinosus.

Thallus loosely adnate to free growing on soil and loose pebbles, leathery and firm, bright yellowish green, 4-8 cm broad; lobes broadly sublinear, 3.5-7 mm wide, separate to imbricate; upper surface continuous, shiny, emaculate, rugose with age; isidia and soredia absent; lower surface plane to broadly convoluted, pale brown, rugose, moderately rhizinate, the rhizines pale brown, 1-1.5 mm long.

Pycnidia not found. Apothecia substipitate, 5-14 mm in diameter, the rim rolled inward; hymenium 43-48 µm; spores 6-7 X 9-11 µm.

Chemistry: Salazinic and usnic acids.

Type collection: On soil on flat dolerite outcrops in pasture, 21 km NW of Sutherland on Hwy R354, elev. 1500 m, Cape Province, S. Africa, Grid 3220 BC, M. E. Hale 74053, 29 Jan. 1986 (US, holotype; PRE, isotype).

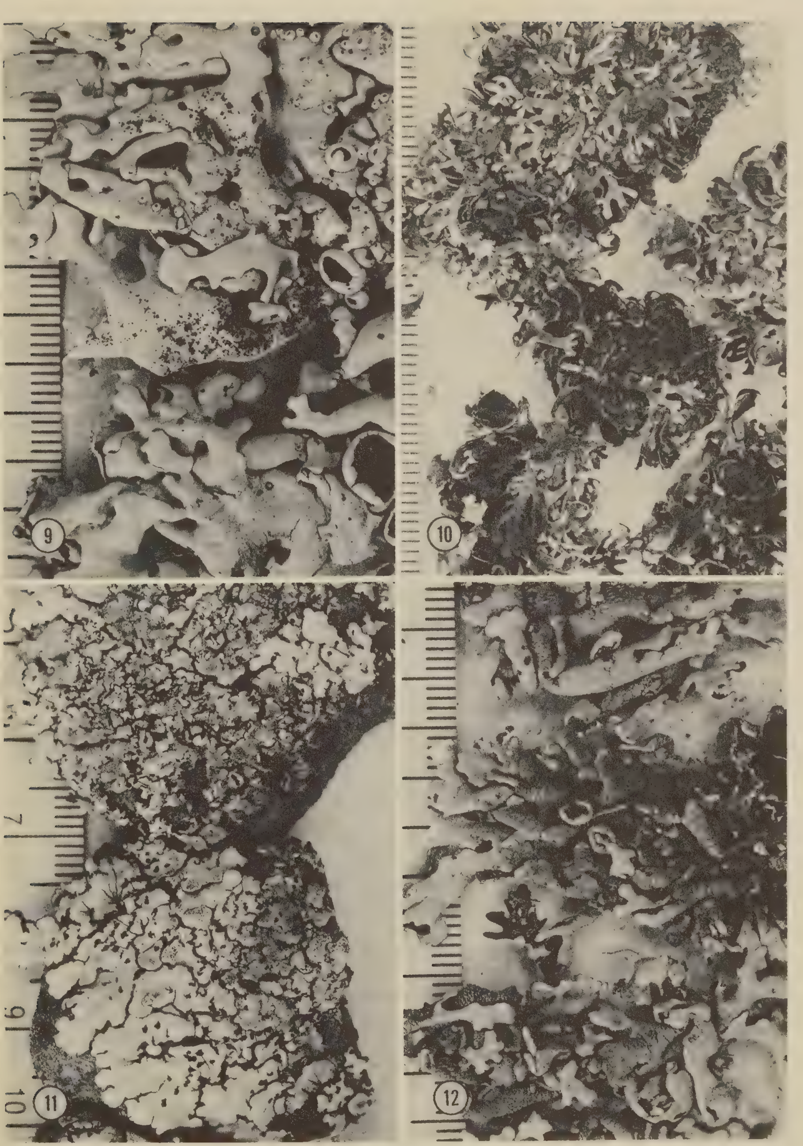
The thallus of this soil-inhabiting lichen is large, leathery, and bright yellow. At first it is easily mistaken for an aberrant X. colorata (Gyelnik) Hale, a very common saxicolous lichen in the karoo, which has migrated to the soil habitat. However, the lower surface is clearly brown, not at all blackened, and the only medullary substance is salazinic acid without norstictic acid. It is much larger, broader lobed and more coriaceous than X. taractica (Kremplh.) Hale, a soil-inhabiting or saxicolous lichen in Australasia and South and Central America. It has been found only in karoo in the south-central part of Cape Province.

Additional specimens examined. S. Africa. Cape Province: Same locality as the holotype, Hale 74077, 74078, 74079, 74080, 74081, 74082, 74083, 74084 (US); 23 km SW of Ladismith, Grid 3321 CA, Hale 74029 (US); 40 km NW of Merweville, Grid 3221 CA, Brusse 3413 (PRE).

Xanthoparmelia denudata Hale, sp. nov. Fig. 10

Thallus laxe adnatus, saxicola, 5-8 cm latus, lobis sublinearibus, 0.6-1.3 mm latis, apice subadscendentibus, superne valde maculatus, isidiis sorediisque destitutus, medulla pro parte ochracea, subtus planus, brunneus, centrum versus ochraceus, sparsissime rhizinosus.

Thallus loosely adnate on rocks, forming continuous mats 5-8 cm broad or discrete, nearly umbilicate colonies 2-4 cm broad, coalescing into mats up to 15 cm broad, dark yellowish green; lobes sublinear, 0.6-1.3 mm wide, separate, ascending at the tips; upper surface distinctly maculate, shiny, transversely cracked with age; isidia and soredia absent; lower surface plane, rugose, brown but eroding toward the center to expose the ochraceous medulla, black at the lobe tips, rhizines very sparse, up to 1 mm long, brown or blackening, coarse.


9
10
11
12
7
9
10

Figures 9-12. Holotypes of *Xanthoparmelia*: 9, *X. crassilobata*; 10, *X. denudata*; 11, *X. diacida*; 12, *X. duplicata*. Scale = mm.

Pycnidia lacking. Apothecia rarely developed, substipitate, 3-6 mm in diameter; hymenium 45-50 µm; spores 6-7 X 8-10 µm (data from Hale 73004).

Chemistry: Salazinic and usnic acids, skyrin.

Type collection: Large exposed sandstone ledges in pasture, 1 km S of Nuwerus on Hwy R363, east of N7, elev. ca 500 m, Cape Province, S. Africa, Grid 3118 AB, M. E. Hale 72041, 26 Jan. 1986 (US, holotype; PRE, isotype).

The pale ochraceous orange lower surface is easily recognizable in the field. The lower cortex erodes away with age to reveal the heavily pigmented lower medulla. The lobe configuration and nearly bare, rugose lower surface resembles X. subcolorata Hale (see below), which has a stronger tendency to form umbilicate thalli, broader lobes (1.5-4 mm wide) and protocetraric acid. Xanthoparmelia hyporhytida (Hale) Hale, also restricted to Namaqualand, has salazinic acid and a similar rugose lower surface eroding with age but lacks skyrin and maculae.

Additional specimens examined. S. Africa. Cape Province: Same locality as the holotype, Hale 72010 (US); 44 km N of Vanrhynsdorp, Grid 3118 BC, Hale 73004, 74114 (US); 1 km E of Springbok, Grid 2917 DB, Hale 72011 (US).

Xanthoparmelia diacida Hale, sp. nov. Fig. 11

Thallus adnatus, saxicola, 5-8 cm latus, lobis subirregularibus, 2-4 mm latis, superne emaculatus, isidiis sorediisque destitutus, medulla pro parte pigmentosa, subtus planus, niger, modice rhizinosus.

Thallus adnate to somewhat loosely attached on rock, 5-8 cm broad, bright yellow green; lobes subirregular, apically rotund, 2-4 mm wide, imbricate and short lobulate with age; upper surface continuous, shiny or rarely white pruinose at the tips, emaculate; isidia and soredia absent; lower part of medulla dull reddish; lower surface plane, black, moderately rhizinate, the rhizines black, simple, 0.5-1 mm long.

Pycnidia not found. Apothecia adnate, 4-5 mm in diameter; hymenium 45 µm; spores 6-7 X 12-15 µm.

Chemistry: Psoromic, protocetraric and usnic acids, an unidentified fatty acid and the "schenckiana" pigment (determined by C. F. Culberson and A. Johnson).

Type collection: Sandstone ridge in high veld, 33.8 km W of Dordrecht on Hwy R56, elev. 800 m, Cape Province, S. Africa, Grid 3126 BC, M. E. Hale 73015, 8 Feb. 1986 (US, holotype; PRE, isotype).

Two other non-isidiate species with psoromic acid, X. huachucensis (Nash) Egan and X. nigropsoromifera (Nash) Egan, also occur in S. Africa. They are both smaller, more tightly adnate lichens lacking both protocetraric acid and the "schenckiana" pigments. Xanthoparmelia schenckiana (Müll. Arg.) Hale, which contains protocetraric acid and the same unidentified dull rusty colored pigment (forming a pale yellow streak near norstictic acid on TLC plates and reacting UV+ yellow fluorescent), is superficially similar but lacks psoromic acid and is usually heavily pruinose. This species is confined to the southern end of the Drakensbergs.

Additional specimen examined. S. Africa. Orange Free State: 18 km E of Marquard, Grid 2827 CB, Venter 4487 (PRE).

Xanthoparmelia duplicata Hale, sp. nov. Fig. 12

Thallus laxe adnatus, terricola, 3-5 cm latus, lobis sublinearibus, 1.5-4 mm latis, superne emaculatus, isidiis sorediisque destitutus, medulla pro parte ochracea, subtus convolutus, brunneus, modice rhizinosus.

Thallus loosely attached to nearly free growing on soil and pebbles, 3-5 cm broad but coalescing into larger colonies, yellowish green; lobes sublinear, 1.5-4 mm wide, separate to imbricate, more or less subascending; upper surface weakly to distinctly maculate, shiny; isidia and soredia absent; medulla ochre in lower parts; lower surface weakly convoluted, brown with ochre spots, sparsely rhizinate, the rhizines brown, 1-2 mm long, coarse, simple to furcate with splayed tips.

Pycnidia not seen. Apothecia well developed, substipitate, 4-8 mm in diameter; hymenium 42-45 µm; spores 6-7 X 9-12 µm.

Chemistry: Protocetraric, 4-O-demethylbarbatic (trace) and usnic acids, a new depside related to diffractaic acid and skyrin (determined by C. F. Culberson and A. Johnson).

Type collection: On soil over quartzite pebbles in flat pasture land, 19.5 km NNW of Vanrhynsdorp on east side of Hwy N7, elev. 200 m, Cape Province, S. Africa, Grid 3118 BC, M. E. Hale 73102, 26 Jan. 1986 (US, holotype; PRE, isotype).

This unique soil-inhabiting lichen is alone among the convoluted species in having this series of acids and the pigment skyrin. It was collected in the quartzite pebble-paved Knersvlakte region of Namaqualand along with X. epigaea Hale (below).

Additional specimen examined. S. Africa. Cape Province: 44 km N of Vanrhynsdorp, Grid 3118 BC, Hale 73106 (US).

Xanthoparmelia effigurata Hale, sp. nov. Fig. 13

Thallus adnatus, coriaceus, 6-12 cm latus, lobis sublinearibus, brevibus, 1.5-2.5 mm latis, superne valde effigurato-maculatus, isidiis sorediisque destitutus, subtus planus, niger, sparse rhizinosus.

Thallus adnate to loosely adnate on rock, firm and leathery, pale yellowish green, 6-12 cm broad; lobes sublinear, 1.5-2.5 mm wide, dichotomously branched; upper surface strongly effigurate maculate, the maculae irregularly elongate, sometimes coalescing, shiny, becoming transversely cracked, somewhat convex with age; isidia and soredia absent; lower surface plane, black with a brown zone at the tips, sparsely to moderately rhizinate, the rhizines coarse, brown to black, 0.5-1 mm long.

Pycnidia common; conidia bifusiform, 0.5 X 6-8 µm. Apothecia commonly developed, substipitate, the rim upturned, 3-7 mm in diameter; hymenium 40-45 µm; spores 6-7 X 9-11 µm.

Chemistry: Salazinic acid, chalybaeizans unknown, and usnic acid, with or without traces of norstictic acid.

Type collection: Schist ledges on hillside, Meiringspoort, 18 km N of De Rust on east side of Hwy R29, elev. 690 m, Cape Province, S. Africa, Grid 3322 BC, M. E. Hale 73016, 1 Feb. 1986 (US, holotype; PRE, isotype).

This effigurate-maculate lichen, common on exposed sandstone outcrops in Namaqualand and southwestern Cape Province, is more or less related to the X. hypoleia group, and is in fact the only one (with X. namakwa Hale (below)) containing salazinic acid. It is, however, not as loosely adnate, almost always being collected with the rock substrate and having more leathery, separate somewhat convex lobes. Xanthoparmelia namakwa Hale (below), a morph with a pale brown lower surface, differs chemically in usually producing salazinic and norstictic acids in equal concentration, only rarely with the chalybaeizans unknown.

Additional specimens examined. S. Africa. Cape Province: Same locality as the holotype, Hale 73100, 73118 (US); 1 km E of Springbok, Grid 2917 DB, Hale 72101 (US); Kamieskroon, Grid 3017 BB, Hale 73002, 73127 (US); 1 km S of Nuwerus, Grid 3118 AB, Hale 72094, 72100 (US); Vanrhyns Pass, Grid 3119 AC, Hale 73130 (US); Nieuwoudtville, Grid 3119 AC, Hale 72006, 72102 (US); Anenouspas, Grid 2917 BA, Hale 73126 (US); 8 km S of Lainsburg, Grid 3320 BB, Hale 75113 (US), Brusse 3535 (LD, PRE); 5 km NW of Wupperthal, Grid 3219 AC, Brusse 3211 (PRE).

Xanthoparmelia endochromatica Hale, sp. nov. Fig. 14

Thallus arcte adnatus, saxicola, 1–2 cm latus, lobis sublineearibus, 0.3–0.9 mm latis, centrum versus opuntioidie constrictis, superne emaculatus, isidiis sorediisque destitutus, medulla aurantio-ochracea, subtus planus, niger, sparse rhizinosus.

Thallus tightly adnate on rock, 1–2 cm broad, yellowish green but blackening with age at the center; lobes sublinear at the margins, strongly black rimmed, 0.3–0.9 mm wide, contiguous, crowded and becoming opuntioid-constricted at the center; isidia and soredia absent; medulla dull rusty red; lower surface plane, black, shiny, sparsely rhizinate, the rhizines coarse, 0.2–0.3 mm long.

Pycnidia and apothecia lacking.

Chemistry: Gyrophoric and usnic acids, "schenckiana" pigment and faint unidentified spots.

Type collection: On Table Mountain sandstone ledges, along trail from Platteklip Gorge to Woodhead Reservoir, Table Mountain Nature Reserve, elev. 950 m, Cape Province, S. Africa, Grid 3318 CD. M. E. Hale 72081, 23 Jan. 1986 (US, holotype; PRE, isotype).

This inconspicuous lichen known from two high elevation localities in southwestern Cape Province is characterized by both chemistry and morphology. It is only the third species of Xanthoparmelia with gyrophoric acid as the main component (the other two are X. leucostigma Brusse and X. gyrophorica Hale (below)). The lobes become rounded and opuntioid-constricted toward the center of the thallus and appear quite unlike any other species in the genus. It is intermixed with X. olivetorica Hale (below), which lacks any pigment and has entirely sublinear lobes.

Additional specimens examined. S. Africa. Cape Province: Summit of Swartberg Pass on R328, Grid 3322 AC, Hale 72082, 72117 (mixtures with X. stenosporonica Hale (below)) (US).

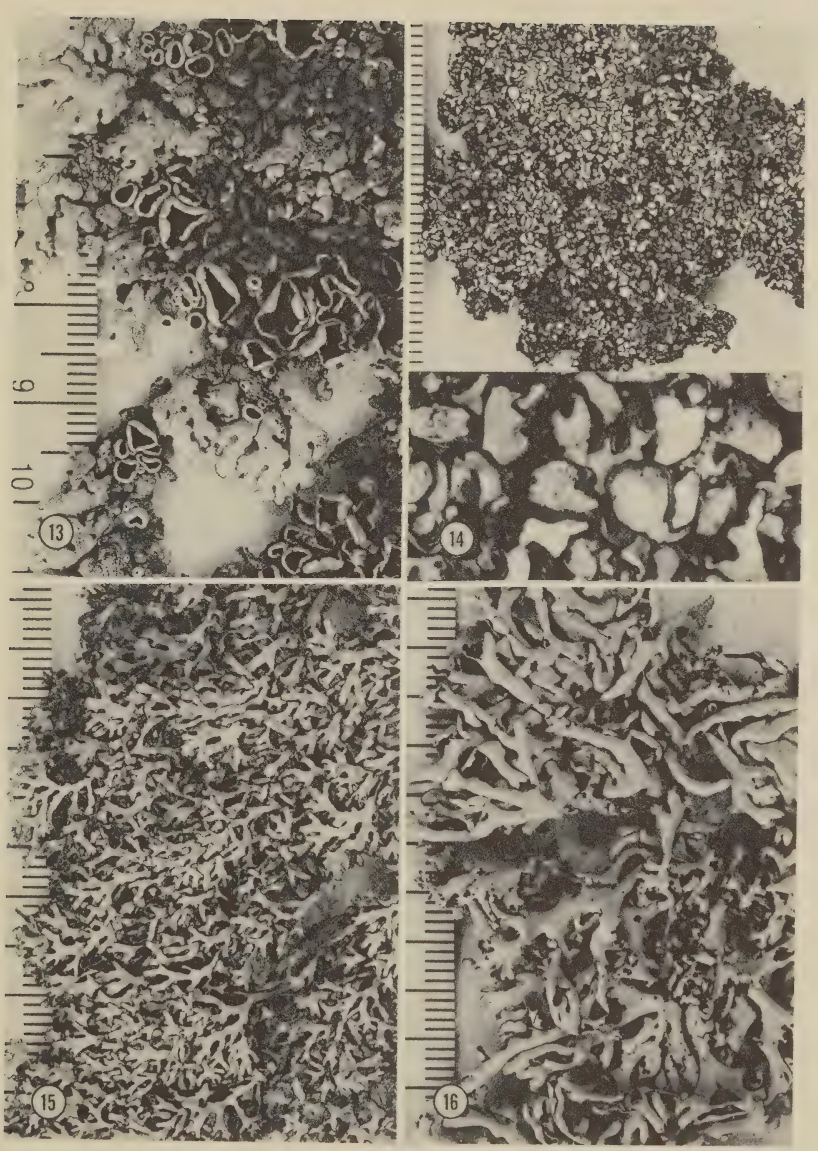
Xanthoparmelia enteroxantha Hale, sp. nov. Fig. 15

Thallus laxe adnatus, saxicola, fragilis, 6–10 cm latus, lobis sublineearibus, elongatis, 1–1.5 mm latis, superne valde maculatus, isidiis sorediisque destitutus, medulla omnino pallide salmoneo-ochracea, subtus planus, niger, modice rhizinosus.

Thallus loosely adnate on rock or on soil over rocks, rather stiff and fragile, 6–10 cm broad, greenish yellow; lobes sublinear, elongate, 1–1.5 mm wide, dichotomously branched, separate to imbricate; upper surface clearly maculate, shiny; isidia and soredia absent; medulla uniformly salmon orange; lower surface plane, dark brown or blackening, sparsely to moderately rhizinate, the rhizines brown to black, rather coarse, 0.5–1 mm long, simple to furcate.

Pycnidia and apothecia lacking.

Chemistry: Salazinic and usnic acids, skyrinol, oxyskyrin, skyrin (trace) and a fourth unidentified anthraquinone (determined by C. F.



Figures 13-16. Holotypes of Xanthoparmelia: 13, X. effigurata; 14, X. endochromatica (lower insert X10); 15, X. enteroxantha; 16, X. epigaea. Scale = mm.

Culberson and A. Johnson).

Type collection: Rock outcrops along Hwy R328, ca 22 km NW of Kango Caves, elev. ca 1000 m, Cape Province, S. Africa, Grid 3322 AC, M. E. Hale 74044, 31 Jan. 1986 (US, holotype; PRE, isotype).

No other species of Xanthoparmelia, excepting X. endomiltoides (Nyl.) Hale, X. endochromatica (Hale) (above) and X. ianthina (Brusse) Hale (comb. nov. based on Parmelia ianthina Brusse in Knox and Brusse, Jour. S. African Bot. 49: 152. 1983), has a completely pigmented medulla. This species occurs at higher elevations in southwestern Cape Province.

Additional specimens examined. S. Africa. Cape Province: Bainskloof, Grid 3319 CA, Hale 72008 (US); Platteklip Gorge to Woodhead Reservoir, Table Mountain Nature Reserve, Grid 3318 CD, Hale 72007 (US).

Xanthoparmelia epigaea Hale, sp. nov. Fig. 16

Thallus laxe adnatus, terricola, coriaceus, 3-5 cm latus, lobis sublinearibus, elongatis, 1.5-5 mm latis, superne emaculatus, isidiis sorediisque destitutus, subtus convolutus, pallide brunneus, dense rhizinosus.

Thallus free growing on soil and pebbles, leathery, covering extensive areas but breaking up into individual colonies 3-5 cm broad, light yellowish green; lobes sublinear, elongate and little branched, 1.5-5 mm wide; upper surface continuous, shiny, emaculate, rugose with age; isidia and soredia absent; lower surface moderately to strongly convoluted, pale brown, densely rhizinate, the rhizines pale brown, 0.5-1.5 mm long, simple to furcate.

Pycnidia common; conidia bifusiform, 0.5 X 6-7 µm. Apothecia sparsely developed, adnate, 2-4 mm in diameter; hymenium 42-45 µm; spores 5-6 X 9-10 µm.

Chemistry: Constipatic and associated fatty acids and usnic acid.

Type collection: Quartzite pebbles and schist in flat pasture land, 19.5 km NNW of Vanrhynsdorp on east side of Hwy N7, elev. 200 m, Cape Province, S. Africa, Grid 3118 BC, M. E. Hale 73020, 26 Jan. 1986 (US, holotype; PRE, isotype).

This soil-inhabiting lichen, probably endemic to the Knersvlakte region of Namaqualand, is related to X. chlorochroa (Tuck.) Hale but differs in being less distinctly convoluted and in having a fatty acid. All other convoluted species contain K+, P+ depsidones or norlobaridone.

Additional specimen examined. S. Africa. Cape Province: Same locality as holotype, Hale 73014 (US); Bowesdorp, Grid 3017 BB, Stokoe 7719 (BOL, US).

Xanthoparmelia equalis Hale, sp. nov. Fig. 17

Thallus arcte adnatus, saxicola, mollis, 5-8 cm latus, lobis sublinearibus, 0.5-1.1 mm latis, congestis vel centro areolato-bullatis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, pallide brunneus, modice rhizinosus.

Thallus adnate to tightly adnate on rocks, soft, 5-8 cm broad, yellowish green; lobes sublinear, short, 0.5-1.1 mm wide, becoming transversely cracked, rather crowded and imbricate to areolate-bullate at the center; upper surface continuous, shiny, faintly reticulate-maculate at the tips; isidia and soredia absent; lower surface plane, pale brown, sparsely to moderately rhizinate, the rhizines pale brown, 0.3-0.5 mm long, simple.

Pycnidia and apothecia lacking.

Chemistry: Evernic, lecanoric (trace) and usnic acids (determined by C. F. Culberson and A. Johnson).

Type collection: Laguneberg Mountains, NE of Mile 72, Distr. Omaruru, S.W.A./Namibia, Grid 2114 CC, M. E. Hale 75101, 8 Jan. 1986 (US, holotype; PRE, isotype).

This Namibian endemic is externally close to X. lagunebergensis Hale (protocetraric acid present) and X. serusiauxii Hale (lecanoric acid present), which occur at the same locality. It differs from the common X. lecanoracea (Müll. Arg.) Hale (comb. nov. with basionym Parmelia lecanoracea Müll. Arg., Flora 71: 529. 1888) in the lack of pruina, distinct yellow color and flatter, shorter, more branched lobes.

Additional specimen examined. S.W.A./Namibia: Same locality as the holotype, Nash s.n. (ASU, US).

Xanthoparmelia esterhuyseniae Hale, sp. nov. Fig. 18

Thallus laxe adnatus, saxicola vel terricola, 4-6 cm latus, lobis sublineairibus, tenuissimis, 0.1-0.3 mm latis, ramis ultimis fere subteretibus, superne emaculatus, isidiis sorediisque destitutus, subtus planus, niger, sparsissime rhizinosus.

Thallus loosely adnate to free growing on soil or rocks, 4-6 cm broad, dark yellowish green to blackening with age; lobes sublinear, elongate, 0.1-0.3 mm wide, dichotomously branched with the ultimate lobes nearly subterete, subascending; upper surface continuous, shiny, emaculate; isidia and soredia absent; lower surface plane, rarely brown or mottled at the tips but black at the center, shiny, very sparsely rhizinate, the rhizines 0.2-0.4 mm long, black.

Pycnidia and apothecia not found.

Chemistry: Stictic, constictic, cryptostictic, norstictic and usnic acids.

Type collection: Sandy flat rock surface on plateau, Hexburg Mountains, elev. 1500 m, Clanwilliam Div., Cape Province, S. Africa, Grid 3319 CB, E. Esterhuysen 18476, 24 March 1951 (BOL, holotype; US, isotype).

This finely branched species, almost looking like a soil-inhabiting Bryoria, usually has subterete ultimate branched, similar to those of X. molliuscula (Ach.) Hale, which is pale brown below and has broader lobes. Another stictic acid-containing species, X. suberadicata (des Abb.) Hale from Madagascar, has broader lobes (to 1 mm wide) and lacks rhizines. The species is named in honor of E. Esterhuysen, who has hiked to the tops of so many difficult high peaks in southwestern Cape Province and discovered a number of new species in the Parmeliaceae.

Additional specimens examined S. Africa. Cape Province: Mt. Superior, Waaihoek Mtns., Grid 3319 AD, Esterhuysen 18236 (BOL); Platteklip near Stellenbosch, Grid 3318 DD, Garside 5037 (BOL, US).

Xanthoparmelia evernica Hale, sp. nov. Fig. 19

Thallus arcte adnatus, saxicola, 3-5 cm latus, lobis sublineairibus, 0.3-1 mm latis, superne emaculatus, aetate albo-pruinosus, isidiatus, isidiis grosse inflatis, globosis, subtus planus, pallide brunneus, modice rhizinosus.

Thallus tightly adnate on rock, 3-5 cm broad, darkish yellow green; lobes sublinear, 0.3-1 mm wide, sparsely dichotomously branched, contiguous, somewhat inflated; upper surface continuous, emaculate, shiny to white pruinose, transversely cracked and rugose with age, isidiate, the isidia coarse, globose and basally constricted, hollow, breaking open at the tips, 0.2-1 mm in diameter, 0.5-1.2 mm high; lower surface plane, pale brown to brown, moderately rhizinate, the rhizines pale brown, 0.3-0.5 mm long.

Pycnidia and apothecia not seen.

Chemistry: Evernic, lecanoric (trace) and usnic acids.

Type collection: Laguneberg Mountains, NE of Mile 72, Distr. Omaruru, S.W.A./Namibia, Grid 2114 CC, M. E. Hale 75106, 8 Jan. 1986 (US, holotype; PRE, isotype).

This is another Namibian endemic clearly distinguished by the unusually large, hollow globose isidia. The pruinose surface and somewhat inflated aspect resemble X. serusiauxii Hale described below but the lower surface color is different.

Additional specimens examined. S.W.A./Namibia. Same locality as holotype, Hale 75105, 75110 (US); Hottentot site, E of Cape Cross, Grid 2114 CA, Hale 75120 (US).

Xanthoparmelia globisidiosa Hale, sp. nov. Fig. 20

Thallus adnatus, saxicola, fragilis, 4-8 cm latus, lobis subirregularibus, 1-2 mm latis, superne emaculatus, isidiatus, isidiis densis, globosis, subtus planus, pallide brunneus, rhizinis nullis.

Thallus adnate on rock, fragile and easily breaking apart when collected, 4-8 cm broad, light yellowish green; lobes subirregular, short, imbricate, 1-2 mm wide; upper surface continuous, shiny, emaculate, isidiate, the isidia dense, globose, basally constricted and breaking off apically, unbranched, 0.10-0.15 mm in diameter, 0.15-0.2 mm high; lower surface plane, shiny, very pale tan, rhizines lacking.

Pycnidia and apothecia lacking.

Chemistry: Stictic, constictic and usnic acids, unknown substance.

Type collection: On large sandstone boulders in pasture, 25 km S of Clanwilliam along Hwy N7, elev. ca 300 m, Cape Province, S. Africa, Grid 3218 DD, M. E. Hale 72030, 25 Jan. 1986 (US, holotype; PRE, isotype).

The most unusual features of this lichen are the lack of rhizines, the very pale brown lower surface color and the globose isidia. It can only be compared with X. treurensis Hale from the eastern Drakensbergs (see below), which is coriaceous and maculate and has a black lower surface and cylindrical isidia. This species is known only from the type locality in Namaqualand.

Xanthoparmelia gyrophorica Hale, sp. nov. Fig. 21

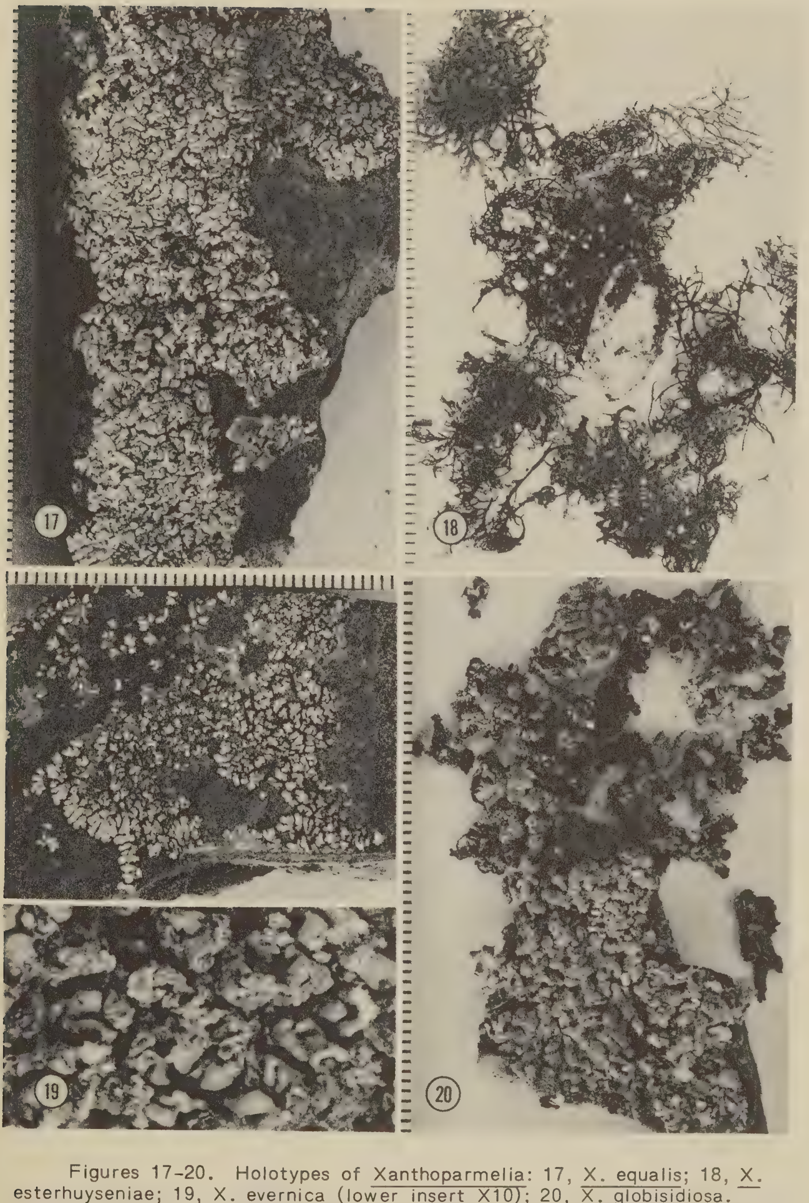
Thallus adnatus, saxicola, coriaceus, 6-12 cm latus, lobis subirregularibus, 2-6 mm latis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, pallide brunneus, modice rhizinosus.

Thallus adnate to loosely adnate on rock, firm, 6-12 cm broad, bright yellowish green; lobes subirregular, apically rotund, contiguous to imbricate, 2-6 mm wide; upper surface continuous, dull, emaculate, transversely cracked with age; isidia and soredia absent; lower surface plane, pale brown, moderately rhizinate, the rhizines brown to blackening, rather coarse, 0.5-1 mm.

Pycnidia numerous; conidia bifusiform, 0.5 X 5-6 µm. Apothecia common, adnate, 5-8 mm in diameter; hymenium 42-45 µm; spores 6-7 X 9-10 µm.

Chemistry: Gyrophoric, lecanoric (trace), 2,4-di-O-methylgyrophoric (trace), 5-O-methylhiascic (trace) and usnic acids (determined by C. F. Culberson and A. Johnson).

Type collection: Exposed dolerite ledges in pasture east of Customs



Figures 17-20. Holotypes of Xanthoparmelia: 17, X. equalis; 18, X. esterhuyseniae; 19, X. evernica (lower insert X10); 20, X. globisidiosa. Scale = mm.

Gate, Sani Pass, elev. 2875 m, Lesotho, Grid 2929 CB, M. E. Hale 74034, 19 Feb. 1986 (US, holotype; PRE, isotype).

Gyrophoric acid is extremely rare in Xanthoparmelia, so far known as the main constituent only in X. leucostigma Brusse, an effigurate-maculate, sublinear lobed species and in X. endochromatica Hale (above), a small tightly adnate lichen with an orange-red medulla. This conspicuous species is very common at Sani Pass and has also been found in the Cathedral Peak area to the north. It will certainly be collected in similar high elevation localities in the eastern escarpment of the Drakensbergs.

Additional specimens examined. Lesotho: Same locality as the holotype, Hale 74032, 74035, 74038, 74039, 74047 (US). S. Africa. Natal: Cathedral Peak area, Grid 2829 CC, Schelpe s.n. (BOL).

Xanthoparmelia hybrida Hale, sp. nov. Fig. 22

Thallus adnatus, saxicola, 6-9 cm latus, lobis subirregularibus, 1-2.5 mm latis, superne emaculatus, valde transversim fissurinus, isidiis sorediisque destitutus, subtus planus, pallide brunneus, modice rhizinosus.

Thallus adnate on rock, 6-9 cm broad, yellowish green; lobes subirregular to sublinear, 1-2.5 mm wide, contiguous to imbricate; upper surface continuous, shiny, emaculate, becoming strongly transversely cracked toward the center; isidia and soredia lacking; lower surface plane, pale brown, moderately to rather densely rhizinate, the rhizines brown, 0.5-1 mm long.

Pycnidia common; conidia bifusiform, 0.5 X 5-6 µm. Apothecia adnate, 2-4 mm in diameter; hymenium 45-50 µm; spores not developed.

Chemistry: Protocetraric, stictic, constictic and usnic acids.

Type collection: On sandstone boulder, Treur River near Bourkes Luck, Pilgrims Rest, elev. 1200 m, Transvaal, South Africa, Grid 2430 DB, M. E. Hale 72083, 14 Jan. 1986 (US, holotype; PRE, isotype).

This rare lichen in the Transvaal Drakensbergs is distinguished by the unique combination of acids, not previously reported in the genus. Morphologically it might be mistaken for a robust specimen of X. cumberlandia (Gyel.) Hale, an American species with stictic acid which also occurs rarely in Cape Province.

Xanthoparmelia indumenica Hale, sp. nov. Fig. 23

Thallus arcte adnatus, saxicola, 4-5 cm latus, lobis brevi-sublineariibus, 0.5-1.5 mm latis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, niger, sparse rhizinosus.

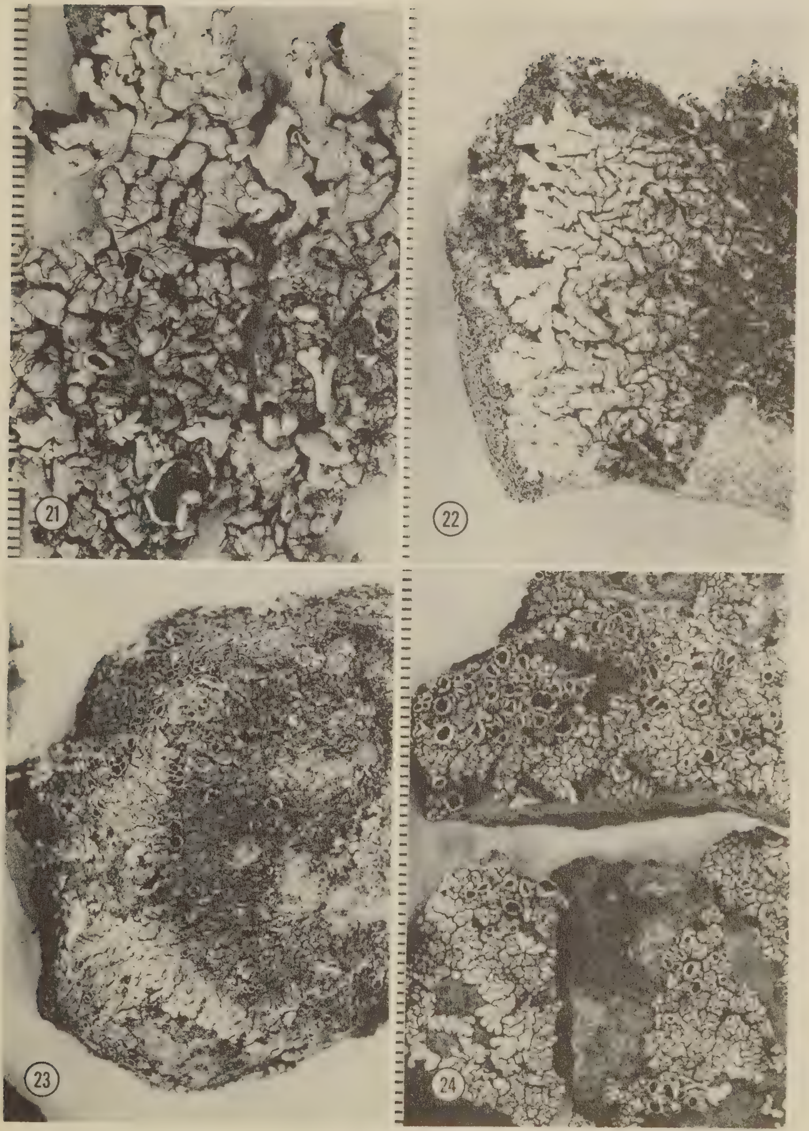
Thallus tightly adnate on rock, 4-5 cm broad, yellowish green but becoming darker green toward the center; lobes sublinear, 0.5-1.5 mm wide, rather short, subimbricate; upper surface continuous, shiny, emaculate; isidia and soredia absent; lower surface plane, black, moderately rhizinate, the rhizines black, rather coarse, 0.1-0.3 mm long.

Pycnidia well developed; conidia bifusiform, 0.5 X 5-6 µm. Apothecia numerous, adnate, 0.6-1 mm in diameter; hymenium 45 µm; spores 5-6 X 9-11 µm.

Chemistry: Stictic, constictic, cryptostictic, norstictic, diffractaic and usnic acids (determined by C. Culberson and A. Johnson).

Type collection: On sandstone boulder, trail to Indumeni Forest/ Rainbow Gorge, Cathedral Peak, elev. 1600 m, Natal, S. Africa, Grid 2829 CC, M. E. Hale 75107 , 22 Feb. 1986 (US, holotype; PRE, isotype).

This inconspicuous lichen in the foothills of the Drakensbergs is



Figures 21-24. Holotypes of Xanthoparmelia: 21, X. gyrophorica; 22, X. hybrida; 23, X. indumenica; 24, X. karooensis. Scale = mm.

characterized by the tightly adnate sublinear lobes, black lower surface and the unique chemistry. Diffractaic acid had not previously been known to occur with stictic acid in the genus. Externally it is comparable to X. adhaerens (Nyl.) Hale, which is subcrustose with lobes less than 0.8 mm wide and contains only stictic and constictic acids.

Xanthoparmelia karooensis Hale, sp. nov. Fig. 24

Thallus arcte adnatus, saxicola, 4-7 cm latus, lobis subirregularibus, brevibus, 0.8-1.5 mm latis, centrum versus congestis, bullatis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, pallide brunneus, modice rhizinosus.

Thallus nearly subcrustose to tightly adnate on rock, 4-7 cm broad, yellowish green; lobes subirregular, short, 0.8-1.5 mm wide, contiguous, becoming crowded and bullate at the center; upper surface continuous, shiny, emaculate; isidia and soredia absent; lower part of medulla ochre; lower surface plane, pale brown, moderately rhizinate, the rhizines pale brown, up to 0.5 mm long.

Chemistry: Hypoprotocetraric, 4-O-demethylnotatic and usnic acids, skyrin and several unidentified minor components.

Pycnidia common; conidia bifusiform, 0.5 X 5-7 µm. Apothecia numerous, adnate, 2-3 mm in diameter; hymenium 44-48 µm; spores 6 X 9 µm.

Type collection: Vertical schist outcrop 8 km S of Lainsburg on Hwy R323, elev. 700 m, Cape Province, S. Africa, Grid 3320 BB, 30 Jan. 1986, M. E. Hale 75102 (US, holotype; PRE, isotype).

This is the only tightly adnate species with hypoprotocetraric acid and skyrin in the genus. It occurs over a wide area in Namaqualand and southwestern Cape Province. Xanthoparmelia subdomokosii (Hale) Hale has the same chemistry but is much larger and loosely adnate.

Additional specimens examined. S. Africa. Cape Province: Same locality as the holotype, Hale 75118 (US); 23 km NNW of Garies, Grid 3017 BB, Hale 72118 (US); 25 km S of Clanwilliam, Grid 3218 DD, Hale 72120 (US); Vanrhyns Pass, Grid 3119 AC, Hale 73129 (US); Anenouspas, Grid 2917 BA, Hale 73121 (US).

Xanthoparmelia lagunebergensis Hale, sp. nov. Fig. 25

Thallus arcte adnatus, saxicola, 2-4 cm latus, lobis sublinearibus, 0.5-1 mm latis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, pallide brunneus, modice rhizinosus.

Thallus tightly adnate on rock, yellowish green, 2-4 cm broad; lobes sublinear, 0.5-1 mm wide, appearing somewhat inflated, separate to contiguous; upper surface continuous, dull, emaculate; isidia and soredia absent; lower surface plane, very pale brown, moderately rhizinate, the rhizines pale, 0.2-0.4 mm long.

Pycnidia and apothecia lacking.

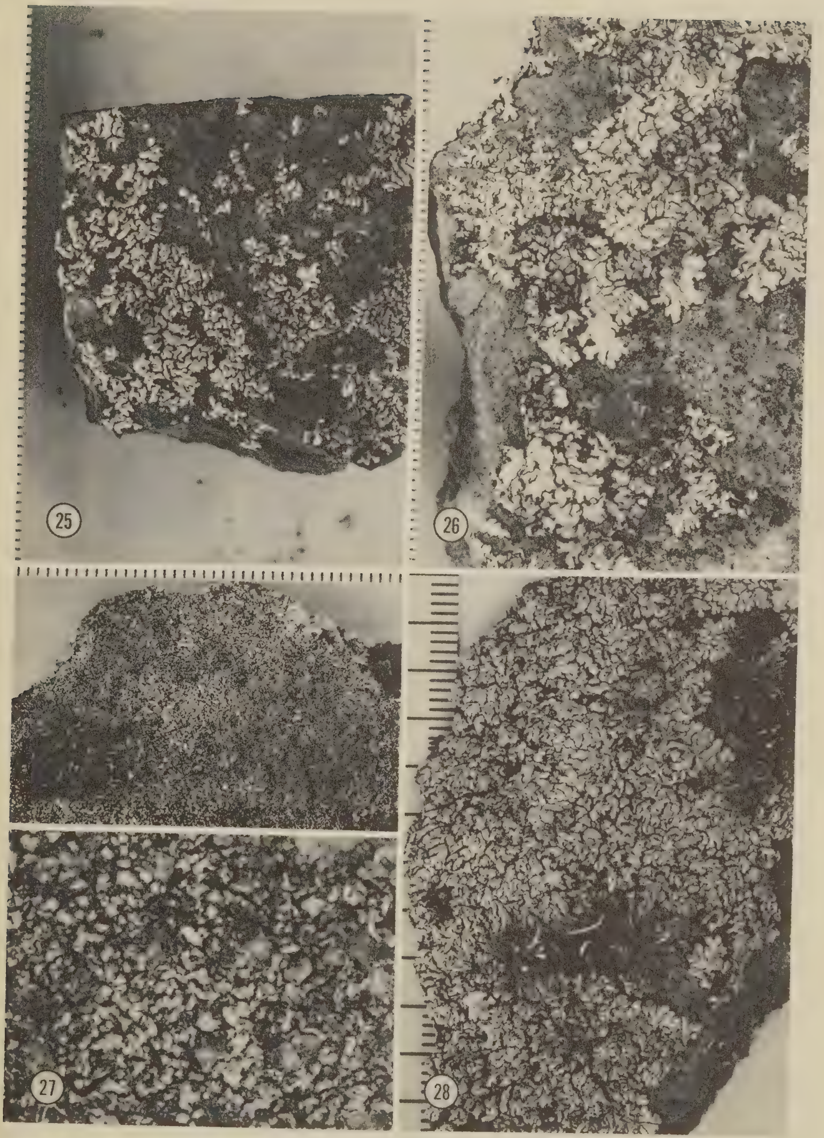
Chemistry: Protocetraric and usnic acids.

Type collection: Laguneberg Mountains, NE of Mile 72, Distr. Omaruru, S.W.A./Namibia, Grid 2114 CC, M. E. Hale 75101, 8 Jan. 1986 (US, holotype; PRE, isotype).

This Namibian endemic is close to X. serusiauxii Hale described below but has a pale lower surface and completely different chemistry and lacks a black rim around the lobe margins.

Xanthoparmelia lesothoensis Hale, sp. nov. Fig. 26

Thallus adnatus, saxicola, 3-5 cm latus, lobis sublinearibus,



Figures 25-28. Holotypes of *Xanthoparmelia*: 25, *X. lagunebergensis*; 26, *X. lesothoensis*; 27, *X. lividica* (lower insert X10); 28, *X. lobulifera*. Scale = mm.

brevibus, 0.8–1.5 mm latis, nigromarginatis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, brunneus, modice rhizinosus.

Thallus adnate to tightly adnate on rock, leathery, 3–5 cm broad, dull yellowish green; lobes sublinear, 0.8–1.5 mm wide, short, dichotomously branched, black rimmed, contiguous to subimbricate; upper surface continuous, shiny, emaculate, transversely cracked with age, isidia and soredia absent; lower surface plane, brown to dark brown, moderately to densely rhizinate, the rhizines coarse, brown, 0.3–0.5 mm long.

Pycnidia common; conidia bifusiform, 0.5 X 6–8 µm. Apothecia not seen.

Chemistry: Salazinic, diffractaic and usnic acids (determined by C. F. Culberson and A. Johnson).

Type collection: Exposed dolerite ledges, pasture east of the Customs Gate, Sani Pass, elev. 2875 m, Lesotho, Grid 2929 CB, M. E. Hale 74093, 17 Feb. 1986 (US, holotype; PRE, isotype).

This small, coriaceous lichen has no close relatives. The combination of salazinic and diffractaic acids is unusual in Xanthoparmelia. It is obviously a high elevation species in the Drakensberg escarpment.

Xanthoparmelia lividica Hale, sp. nov. Fig. 27

Thallus arctissime adnatus, saxicola, 2–4 cm latus, lobis sublinearibus, 0.1–0.2 mm latis, nigromarginatis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, niger, modice rhizinosus.

Thallus very tightly adnate on rocks, 2–4 cm broad, yellow green at the margins but becoming darker, almost black at the center; lobes sublinear, 0.1–0.2 mm wide, black rimmed, contiguous to crowded at the center; surface continuous, shiny, emaculate; isidia and soredia absent; lower surface plane, black, shiny, moderately rhizinate, the rhizines black, ca 0.1 mm long.

Pycnidia and apothecia not found.

Chemistry: Lividic, colensoic and usnic acids (with two other faint spots in the colensoic acid series).

Type collection: On Table Mountain sandstone ledges in Fynbos above ocean, Olifantsbaai, Cape of Good Hope Nature Reserve, elev. 20 m, Cape Province, S. Africa, Grid 3418 AD, M. E. Hale 74092, 21 Jan. 1986 (US, holotype; PRE, isotype).

This tiny lichen, with perhaps the smallest lobes of any Xanthoparmelia, is barely discernible on the surface of coarse sandstone ledges. In size and general morphology it is closest to X. olivetorica Hale (below), but the chemistry separates it from this and all other species of Xanthoparmelia.

Xanthoparmelia lobulifera Hale, sp. nov. Fig. 28

Thallus arcte adnatus, saxicola, 5–8 cm latus, lobis sublinearibus, 0.6–1 mm latis, congestis, convexis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, niger, rhizinis nullis.

Thallus tightly adnate on rock, firm, 5–8 cm broad, bright yellow green; lobes sublinear, 0.6–1 mm wide, imbricate and congested, branching into narrow secondary lobes 0.4–0.6 mm wide, appressed to subascending; upper surface continuous, dull to shiny, convex, emaculate, rugose and transversely cracked with age; isidia and soredia absent; lower surface plane to slightly grooved, black, dull, rhizines lacking.

Pycnidia and apothecia lacking.

Chemistry: Stictic, constictic and usnic acids.

Type collection: On sandstone in pasture, 37.4 km NW of Queenstown along Hwy R30, elev. ca 1600 m, Cape Province, S. Africa, Grid 3126 AC, M. E. Hale 72025, 8 Feb. 1986 (US, holotype; PRE, isotype).

There seem to be no close relatives for this eastern Cape Province lichen. The black lower surface without rhizines and the leathery, crowded lobes are distinctive.

Additional specimen examined. S. Africa. Cape Province: Same locality as the holotype, Hale 72029 (US).

Xanthoparmelia minuta Knox and Hale, sp. nov. Fig. 29

Thallus arcte adnatus, saxicola, 1–1.5 cm latus, lobis sublinearibus, 0.4–0.8 mm latis, nigromarginatis, superne emaculatus, isidiatus, isidiis cylindricis, subtus planus, niger, modice rhizinosus.

Thallus tightly adnate on rocks, 1–1.5 cm broad, yellowish green; lobes sublinear, dichotomously branched, 0.4–0.8 mm wide, short, black rimmed, contiguous; upper surface continuous, shiny, emaculate, isidiate, the isidia sparse to moderate, cylindrical, black tipped, unbranched, 0.06–0.07 mm in diameter, 0.09–0.1 mm high; lower surface plane, black, moderately rhizinate, the rhizines black, 0.3–0.5 mm long, simple.

Pycnidia and apothecia lacking.

Chemistry: Norstictic and salazinic acids in nearly equal concentration, consalazinic, gyrophoric (trace), protoconstipatic (trace) and usnic acids (determined by T. Nash, J. Elix and J. Johnston).

Type collection: Open sandstone cliffs, Mt. Sheba Nature Reserve, Pilgrims Rest, elev. 1965 m, Transvaal, S. Africa, Grid 2430 DC, M. E. Hale 72108, 15 Jan. 1986 (US, holotype; PRE, isotype).

This inconspicuous species, highly localized at higher elevations in the Transvaal Drakensberg escarpment, is reminiscent of X. mougeotina (Nyl.) Galloway, but the lobes are consistently narrower and the chemistry is quite different (X. mougeotina has stictic acid).

Additional specimens examined. S. Africa. Transvaal: Same locality as the holotype, Hale 72116, 72117 (US); near Houbosdorp, Magoebaskloof, Grid 2330 CC, Nash 23337 (ASU, US). Natal: Umtanvuna Forest Reserve, Grid 3130 AA, Knox 269 (J, US).

Xanthoparmelia mollis Hale, sp. nov. Fig. 30

Thallus laxe adnatus, saxicola, mollis, usque ad 20 cm latus, lobis lineari-elongatis, 0.5–0.7 mm latis, apice vix teretibus, superne indistincte maculatus, isidiis sorediisque destitutus, subtus planus, niger, rugosus, sparse rhizinosus.

Thallus loosely adnate on flat rocks, soft, forming extensive centrifugate colonies up to 20 cm broad, yellowish green; lobes linear-elongate, dichotomously branched, 0.5–0.7 mm wide, the ultimate lobes nearly terete; upper surface becoming indistinctly maculate, shiny; isidia and soredia absent; lower surface plane, black, rugose, rhizines almost completely lacking except for a few at lobe tips.

Pycnidia and apothecia lacking.

Chemistry: Protocetraric and usnic acids.

Type collection: On flat sandstone exposures back from cliff edge, Oribi Gorge Nature Reserve, elev. 300 m, Natal, S. Africa, Grid 3030 CB, M. E. Hale 74043, 3 Feb. 1986 (US, holotype; PRE, isotype).

This species is in the X. hypoleia group but the thallus forms soft centrifugate colonies, the lobes are uniformly narrow and the surface is not strongly effigurate-maculate. It was found in abundance with X.

subruginosa Hale (below) on flat, exposed ledges at Oribi Gorge.

Additional specimen examined. S. Africa. Natal: Same locality as holotype, Hale 74017 (US).

Xanthoparmelia namakwa Hale, sp. nov. Fig. 31

Thallus adnatus, saxicola, coriaceus, 4-8 cm latus, lobis sublinearibus, contiguis, 1-2 mm latis, superne effigurato-maculatus, isidiis sorediisque destitutus, subtus planus, pallide brunneus, modice rhizinosus.

Thallus adnate on rock, rather firm and leathery, 4-8 cm broad, darkish yellow-green; lobes sublinear, 1-2 mm wide, contiguous; upper surface strongly effigurate-maculate, the maculae elongate, sometimes coalescing, shiny, becoming rugose with age toward the center; isidia and soredia absent; lower surface plane to slightly concave, uniformly pale brown or turning nearly black only at the tips, sparsely to moderately rhizinate, the rhizines coarse, 0.5-1 mm long.

Pycnidia abundantly developed; conidia bifusiform, 0.5 X 5-6 µm. Apothecia common, substipitate, 1-5 mm in diameter; hymenium 45-48 µm; spores 5-6 X 9-11 µm.

Chemistry: Salazinic and norstictic acids in nearly equal concentration, usnic acid, with or without traces of the chalybaeizans unknown, or rarely with salazinic acid alone.

Type collection: On schist outcrops in flat pasture land, 19.5 km NNW of Vanrhynsdorp on east side of Hwy N7, elev. 200 m, Cape Province, S. Africa, Grid 3118 BC, M. E. Hale 73072, 26 Jan. 1986 (US, holotype; PRE, isotype).

This Namaqualand karoo lichen is close to X. effigurata Hale (above), which has a uniformly black lower surface and predominantly salazinic acid and the chalybaeizans unknown. The two species have only been collected together at Anenouspas. Another closely related species, X. exornata (Stein. & Zahlbr.) Knox, has strongly convex lobes, coarse rhizines and recessed, pseudocyphella-like maculae.

Additional specimens examined. S. Africa. Cape Province: Same locality as the holotype, Hale 73061, 73071 (US); Anenouspas, Grid 2917 BA, Hale 73062, 73070 (US); 44 km N of Vanrhynsdorp, Grid 3118 BC, Hale 73073 (US); 4.9 km S of Lainsburg, Grid 3320 BB, Hale 73074 (US).

Xanthoparmelia namaquensis Hale, sp. nov. Fig. 32

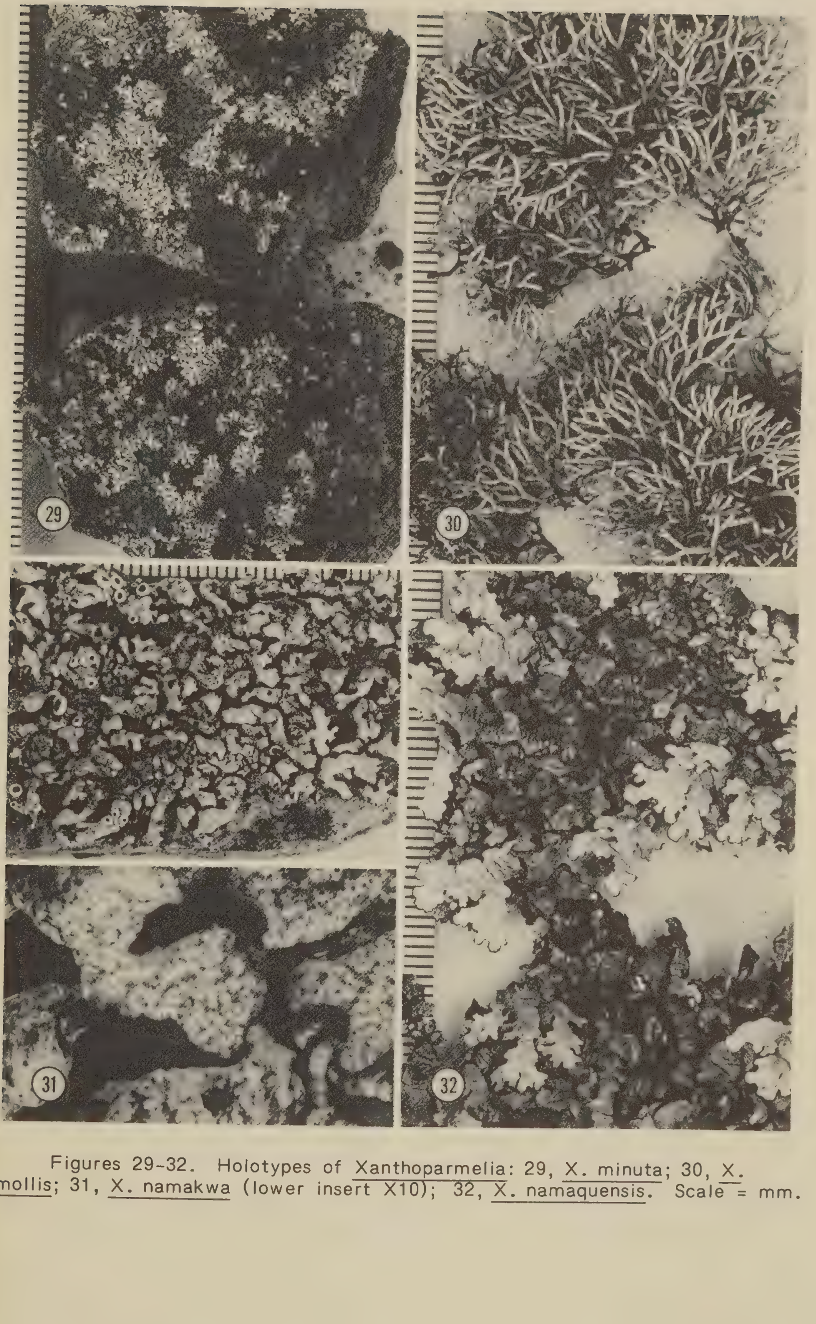
Thallus laxe adnatus, saxicola, 6-12 cm latus, lobis sublinearibus, 2-5 mm latis, superne continuus vel vix maculatus, isidiis sorediisque destitutus, medulla partim purpurea, subtus planus, niger, sparse rhizinosus.

Thallus loosely adnate on rock, easily breaking apart, 6-12 cm broad, yellowish green but darkening at the center; lobes sublinear, rather short and crowded, 2-5 mm wide, contiguous to imbricate; upper surface continuous to very weakly maculate, shiny, transversely cracked with age; isidia and soredia absent; lower part of medulla in part dark purple; lower surface plane, black, dull, sparsely rhizinate, the rhizines black, coarse, 0.5-1 mm long.

Pycnidia and apothecia lacking.

Chemistry: Lecanoric and usnic acids, a bright pinkish orange anthraquinone pigment on extraction with acetone (detected only in decomposing parts of the medulla) (determined by C. F. Culberson and A. Johnson).

Type collection: Exposed sandstone cliff on edge of escarpment, 41



Figures 29-32. Holotypes of *Xanthoparmelia*: 29, *X. minuta*; 30, *X. mollis*; 31, *X. namakwa* (lower insert X10); 32, *X. namaquensis*. Scale = mm.

km NE of Vanrhynsdorp at Vanrhyns Pass along Hwy R27, elev. 800 m, Cape Province, S. Africa, Grid 3119 AC, M. E. Hale 73018, 28 Jan. 1986 (US, holotype; PRE, isotype).

Of the eight species of Xanthoparmelia with lecanoric acid, this is the only one that is clearly loosely adnate. It produces a unique deep pinkish orange pigment reacting K+ light purple and probably related (but not equal) to the anthraquinone series in X. endomiltoides. It is apparently restricted to Namaqualand.

Additional specimens examined. S. Africa. Cape Province: Same locality as the holotype, Hale 73131 (US); 1 km S of Nuwerus, Grid 3118 AB, Hale 72114 (US).

Xanthoparmelia neosynestia Hale, sp. nov. Fig. 33

Thallus adnatus vel laxe adnatus, saxicola, 4–7 cm latus, lobis sublinearibus, 1–2.5 mm latis, superne maculatus, isidiis sorediisque destitutus, subtus planus, pallide brunneus, modice rhizinosus.

Thallus adnate to loosely adnate on rock, rather brittle, dark greenish yellow, 4–7 cm broad; lobes sublinear to subirregular, 1–2.5 mm wide, short and imbricate; upper surface uniformly maculate, shiny, transversely cracked with age; isidia and soredia absent; lower surface plane, pale brown to brown, sparsely to moderately rhizinate, the rhizines brown, 0.5–1 mm long, simple.

Pycnidia numerous; conidia bifusiform, 0.5 X 5–6 µm. Apothecia well developed, adnate, 3–5 mm in diameter, the rim crenate; hymenium 40–45 µm; spores 5–6 X 9–10 µm.

Chemistry: Salazinic, norstictic (trace), protocetraric (trace), consalazinic and usnic acids, with or without the chalybaeizans unknown (present in holotype) (determined by T. Nash and J. Elix).

Type collection: Exposed sandstone cliffs on escarpment in hillside karoo, 41 km NE of Vanrhynsdorp at Vanrhyns Pass on Hwy R27, elev. 800 m, Cape Province, S. Africa, Grid 3119 AC, M. E. Hale 73017, 28 Jan. 1986 (US, holotype; PRE, isotype).

This species has the same distinctive dull yellowish green cast of X. synestia (Stirt.) Hale but the lower surface is uniformly pale or darker brown but not blackening. It occurs over a broad area in Namaqualand and southwestern Cape Province.

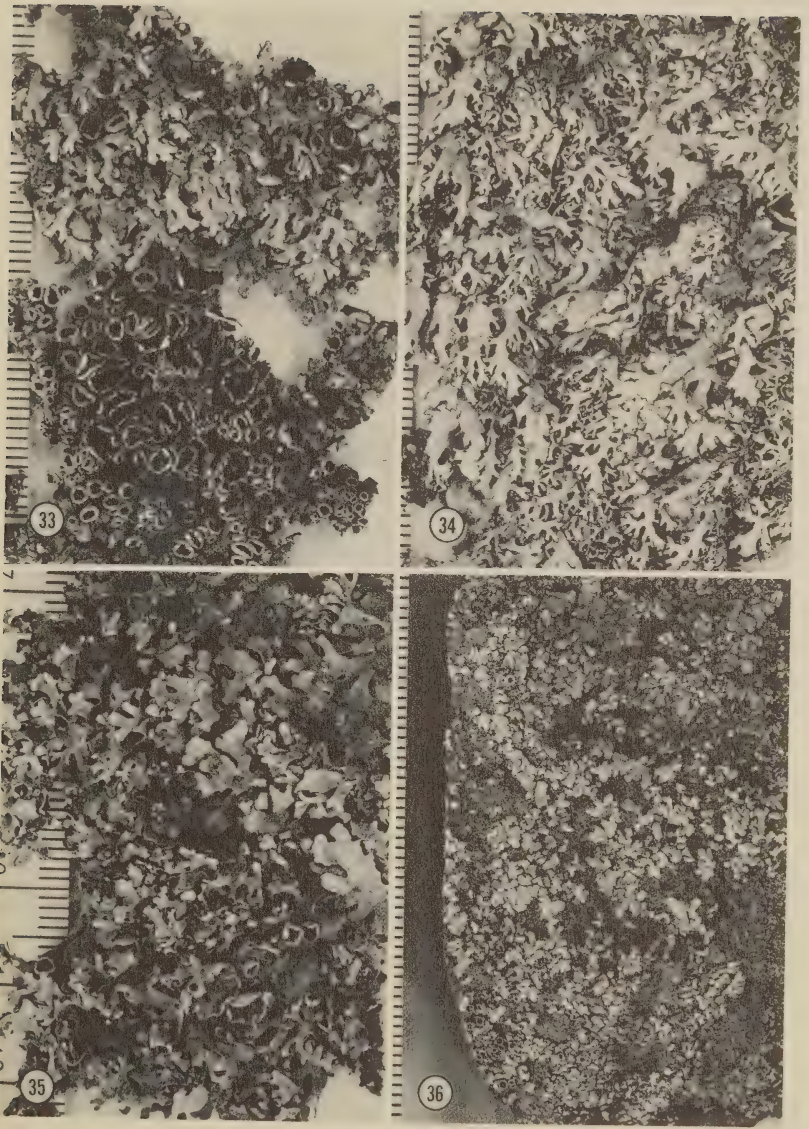
Additional specimens examined. S. Africa. Cape Province: 1 km E of Springbok, Grid 2917 DB, Hale 72095 (US); Pakhuis Pass, Grid 3218 BB, Hale 72119 (US); Camps Bay, Grid 3318 CD, Almborn 4393, 4395 (LD, US); Bainskloof Pass, Grid 3319 CA, Hale 72121 (US), Nash 23519 (ASU, US), Sipman 20234 (B); 26.4 km E of Ladismith, Grid 3321 AD, Hale 73144 (US); Meiringspoort, Grid 3322 BC, Hale 73143 (US).

Xanthoparmelia neotasmanica Hale, sp. nov. Fig. 34

Thallus laxe adnatus, saxicola, 10–15 cm latus, lobis sublinearibus, 2–2.5 mm latis, centrum versus laciniatis, superne leviter maculatus, isidiis sorediisque destitutus, subtus planus, niger, modice rhizinosus.

Thallus loosely adnate, often growing in mats on tops and sides of sheltered rocks, 10–15 cm broad, light yellowish green; lobes sublinear, 2–2.5 mm wide, branching into numerous short laciniae about 0.6–1.0 mm wide toward the center; upper surface weakly to distinctly maculate, shiny, isidia and soredia absent; lower surface plane, black, moderately to densely rhizinate, the rhizines black, 0.5–1 mm long.

Pycnidia abundant; conidia bifusiform, 0.5 X 6–7 µm. Apothecia



Figures 33-36. Holotypes of *Xanthoparmelia*: 33, *X. neosynestia*; 34, *X. neotasmanica*; 35, *X. nuwarensis*; 36, *X. ochropulchra*. Scale = mm.

rather rare, adnate, 4-9 mm in diameter; hymenium 45-48 µm; spores 5-6 X 9-10 µm (data from Hale 73019).

Chemistry: Salazinic and usnic acids.

Type collection: Exfoliating granitic outcrops in karoo, 78.6 km S of Sutherland on Hwy R354, Cape Province, S. Africa, Grid 3220 DC, M. E. Hale 73019, 29 Jan. 1986 (US, holotype; PRE, isotype).

The X. tasmanica group encompasses a wide range of variation in lobe width and surface features. Xanthoparmelia tasmanica (Hook. & Tayl.) Hale itself is a very common species in S. Africa, as well as in North America and Australasia. This new species represents one extreme, consistently producing marginal laciniae and having fairly distinct, uniform maculae, characters lacking in typical X. tasmanica. It has a wide range in southwestern Cape Province.

Additional specimens examined. S. Africa. Cape Province: Lions Head, Cape Div., Grid 3318 AB, Almborn & Karnefelt 8411-10 (LD); Moltenopas, Grid 3222 BA, Hale 73006 (US); Nieuwoudtville Nature Reserve, Grid 3119 AC, Hale 72012 (US); Meiringspoort, Grid 3322 BC, Hale 73005 (US).

Xanthoparmelia nuwarensis Hale, sp. nov. Fig. 35

Thallus laxe adnatus, saxicola, 6-9 cm latus, lobis sublinearibus, 1.5-3 mm latis, apice subadscendentibus, superne valde maculatus, subtus planus, brunneus, sparse rhizinosus.

Thallus loosely adnate on rocks, breaking apart, 6-9 cm broad, dark greenish yellow; lobes sublinear, 1.5-3 mm wide, dichotomously branched, separate to imbricate, the tips curling up somewhat; upper surface strongly maculate, shiny; isidia and soredia absent; lower surface plane, becoming rugose in part, black at the tips but brown to pale brown toward the center, sparsely to moderately rhizinate, the rhizines brown, 0.5-1 mm long, rather coarse.

Pycnidia commonly developed; conidia bifusiform, 0.5 X 6-7 µm. Apothecia substipitate, 3-6 mm in diameter; hymenium 43-46 µm; spores 5-6 X 9-11 µm.

Chemistry: Fumarprotocetraric, succinprotocetraric and usnic acids.

Type collection: Large exposed sandstone ledge and ridges in pasture, 1 km S of Nuwerus on Hwy 363, elev. ca 500 m, Cape Province, S. Africa, Grid 3118 AB, M. E. Hale 72111, 26 Jan. 1986 (US, holotype; PRE, isotype).

This Namaqualand lichen is a member of the highly variable X. phaeophana (Stirt.) Hale complex. It is differentiated by the darker green color, strong white maculation as in X. synestia (Stirt.) Hale, and the rugose, brown lower surface. Xanthoparmelia viridis Hale (below) is very close and has the same chemistry but differs in being black below.

Additional specimen examined. S. Africa. Cape Province: 23 km NNW of Garies, Grid 3017 BB, Hale 72112 (US).

Xanthoparmelia ochropulchra Hale, sp. nov. Fig. 36

Thallus arcte adnatus, saxicola, friabilis, 3-8 cm latus, lobis subirregularibus, 0.6-1.4 mm latis, superne emaculatus, isidiis sorediisque destitutus, medulla pro parte ochracea, subtus planus, pallide brunneus, sparse rhizinosus.

Thallus tightly adnate, soft and friable, 3-8 cm broad, yellowish green; lobes subirregular, 0.6-1.4 mm wide, contiguous to subimbricate; upper surface continuous, shiny, weakly reticulate-maculate and minutely rugulose at the tips; isidia and soredia absent; medulla pale orange in the lower parts; lower surface plane, pale brown, sparsely rhizinate, the

the rhizines pale brown, 0.2–0.4 mm long.

Pycnidia common; conidia bifusiform, 0.5 X 5–6 µm. Apothecia well developed, adnate, 1–1.5 mm in diameter; hymenium 40–43 µm; spores 5 X 8–9 µm.

Chemistry: A new depside related to diffractaic acid and usnic acid, endocrocin and an unidentified anthraquinone pigment (determined by C. F. Culberson and A. Johnson).

Type collection: Exfoliating granitic outcrops in karoo, 78.6 km S of Sutherland on Hwy R354, elev. ca 900 m, Cape Province, S. Africa, Grid 3220 DC, M. E. Hale 73101, 29 Jan. 1986 (US, holotype; PRE, isotype).

Known only from one locality in the karoo of southwestern Cape Province, this species has no obvious relatives in Xanthoparmelia. The yellow pigments, presence of a new depside near diffractaic acid (also present in X. duplicata Hale (above)) and small, friable, short-lobed thallus are all unique.

Xanthoparmelia olifantensis Hale, sp. nov. Fig. 37

Thallus arcte adnatus, 2–3 cm latus, lobis sublinearibus, 0.4–0.6 mm latis, centrum versus subareolatis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, niger, sparse rhizinosus.

Thallus tightly adnate to almost subcrustose, 2–3 cm broad, yellowish green; lobes sublinear, 0.4–0.6 mm wide, sparsely dichotomously branched, cracked and subareolate toward the center; upper surface continuous, shiny, emaculate, transversely cracked; isidia and soredia absent; lower surface plane, black, sparsely rhizinate, the rhizines black, 0.2–0.3 mm long.

Pycnidia and apothecia lacking.

Chemistry: Norstictic, salazinic and usnic acids.

Type collection: On ledges above beach, Olifantsbaai, Cape of Good Hope Nature Reserve, elev. 20 m, Cape Province, S. Africa, Grid 3418 AD, M. E. Hale 72113, 21 Jan. 1986 (US, holotype; PRE, isotype).

A similar species is X. minuta Knox & Hale (see above), which also contains norstictic and salazinic acids in nearly equal concentration but differs in having isidia and a trace of gyrophoric acid. This species is apparently restricted to the rocky hillsides exposed to southwesterly rain and mist in the Cape area.

Additional specimens examined. S. Africa. Cape Province: Same locality as the holotype, Hale 75119 (US); Kogelberg Range, Grid 3418 BD, Leighton 716 (BOL).

Xanthoparmelia olivetorica Hale, sp. nov. Fig. 38

Thallus arcte adnatus, 1–3 cm latus, saxicola, lobis sublinearibus, 0.2–0.6 mm latis, valde nigromarginatis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, niger, sparse rhizinosus.

Thallus tightly adnate on rock, 1–3 cm broad, dark greenish yellow but blackening with age toward the center; lobes sublinear, 0.2–0.6 mm wide, strongly black rimmed, contiguous; upper surface continuous, shiny, transversely cracked with age, isidia and soredia absent; lower surface plane, black, shiny, sparsely rhizinate, the rhizines black, about 0.2 mm long.

Pycnidia and apothecia lacking.

Chemistry: Olivetoric and usnic acids.

Type collection: On sheltered sandstone ledges along trail from Platteklip Gorge to Woodhead Reservoir, Table Mountain Nature Reserve, Cape Province, S. Africa, Grid 3318 CD, M. E. Hale 72079, 23 Jan. 1986

(US, holotype; PRE, isotype).

The appressed thallus with very narrow lobes resembles X. lividica Hale (above) but is more robust. Another species with olivetoric acid, X. heterodoxa Hale (described from Natal Table Mountain), is larger, less tightly adnate and lacks a black margin around the lobes. These are the only species in Xanthoparmelia with olivetoric acid.

Additional specimen examined. Same locality as the holotype, Hale 72080 (US).

Xanthoparmelia oribensis Hale, sp. nov. Fig. 39

Thallus adnatus, saxicola, 6–12 cm latus, lobis subirregularibus, 2–4 mm latis, superne emaculatus, isidiatus, isidiis densis, cylindricis, medulla pro parte ochracea, subtus planus, niger, modice rhizinosus.

Thallus adnate to closely adnate on flat rocks, 6–12 cm broad, yellowish green; lobes subirregular to sublinear, 2–4 mm wide, contiguous; upper surface continuous, shiny, emaculate, transversely cracked with age, isidiate, the isidia moderate to dense, tall, cylindrical, simple or branched, 0.1–0.12 mm in diameter, 0.5–1 mm high; lower part of medulla orange-red; lower surface plane, black but ochre when lower cortex breaks open, sparsely to moderately rhizinate, the rhizines black, simple, 0.5–1 mm long.

Pycnidia and apothecia lacking.

Chemistry: Hypoprotocetraric, 4-O-demethylnotatic and usnic acids, skyrin and several minor unidentified components.

Type collection: Flat sandstone exposures back from the cliff, Oribi Gorge Nature Reserve, elev. 300 m, Natal, S. Africa, Grid 3030 CB, M. E. Hale 74041, 3 Feb. 1986 (US, holotype; PRE, isotype).

The only other species in Xanthoparmelia with hypoprotocetraric acid and a black lower surface is subcrustose X. neocongensis (Hale) Hale, which is also isidiate but lacks skyrin. Two other African species with hypoprotocetraric acid and skyrin, X. karooensis Hale (above) and X. subdomokosii (Hale) Hale, lack isidia. Xanthoparmelia oribensis is known only from the spectacular sandstone cliffs overlooking Oribi Gorge.

Additional specimens examined. S. Africa. Natal: Same locality as the holotype, Hale 74054, 74055 (US).

Xanthoparmelia probarbellata Hale, sp. nov. Fig. 40

Thallus adnatus, saxicola, 4–6 cm latus, lobis sublinearibus, 2–3 mm latis, superne emaculatus, isidiis sorediisque destitutus, medulla pro parte ochracea, subtus planus, pallide brunneus, modice rhizinosus.

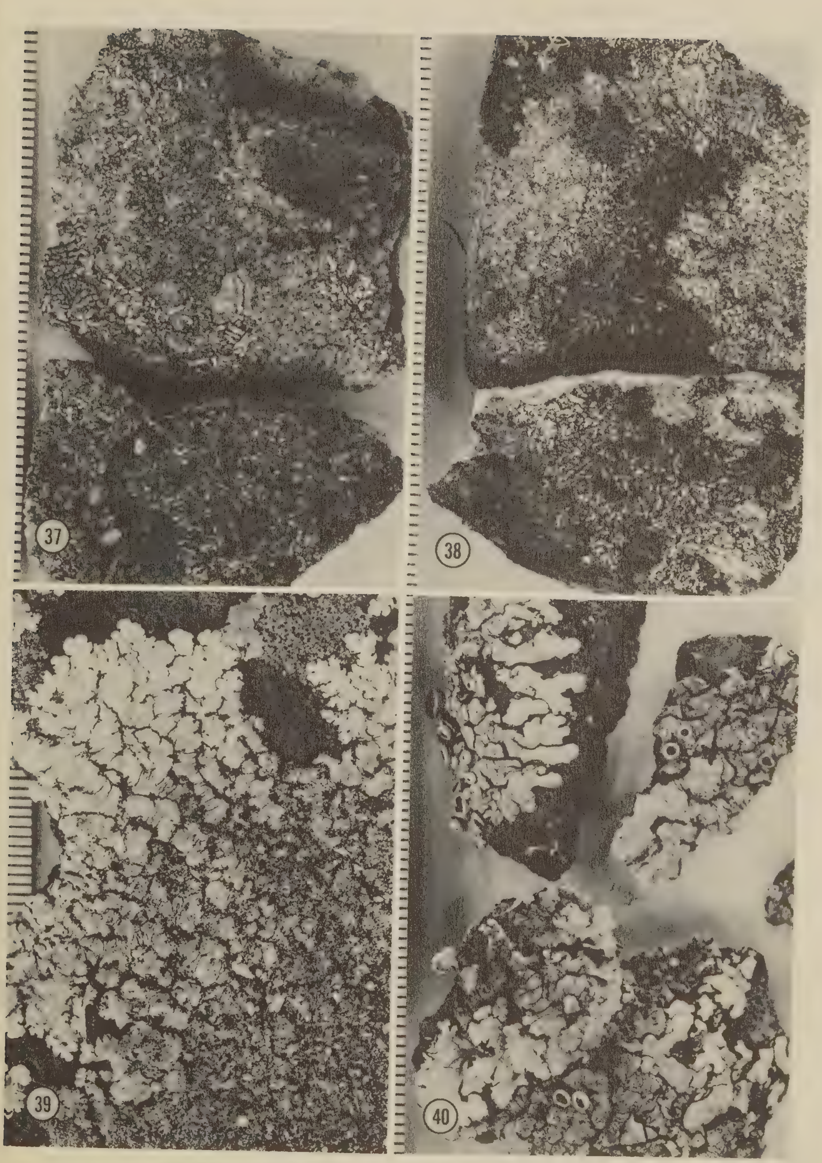
Thallus adnate on rock, 4–6 cm broad, yellowish green; lobes sublinear, 2–3 mm wide, somewhat separate to contiguous; upper surface continuous, shiny, emaculate; isidia and soredia absent; medulla ochre in the lower part; lower surface plane, pale brown to brown, moderately rhizinate, the rhizines brown, 0.5–1 mm long.

Pycnidia numerous; conidia bifusiform, 0.5 X 5–6 µm. Apothecia numerous, adnate, 3–5 mm in diameter; hymenium 40–45 µm; spores 5–6 X 8–9 µm.

Chemistry: Salazinic and norstictic acids in nearly equal concentration, trace of chalybaeizans unknown, usnic acid, and skyrin.

Type collection: Soft conglomerate sandstone ridges in pasture, 52.5 km SE of Lady Grey on Hwy R58, elev. ca 1900 m, Cape Province, S. Africa, Grid 3027 CD, M. E. Hale 72109, 9 Feb. 1986 (US, holotype; PRE, isotype).

An Australian species, X. barbellata (Kurok.) Hale, has similar



Figures 37-40. Holotypes of Xanthoparmelia: 37, X. olifantensis; 38, X. olivetorica; 39, X. oribensis; 40, X. probarbellata. Scale = mm.

chemistry (except for the lack of the chalybaeizans unknown) but is more loosely adnate and may occur on soil as well as rocks. Xanthoparmelia probarbellata is known only from the type collection in eastern Cape Province.

Xanthoparmelia pustulifera Hale, Nash and Elix, sp. nov. Fig. 41

Thallus adnatus, saxicola, 5–8 cm latus, lobis sublinearibus, brevibus, 0.5–1.2 mm latis, imbricatis, superne emaculatus, isidiatus, isidiis globosis, eruptentibus pustulescentibusque, subtus planus, niger, modice rhizinosus.

Thallus adnate to tightly adnate on rock, fragile, 5–8 cm broad, dull yellowish green; lobes short and sublinear, dichotomously branched, 0.5–1.2 mm wide, contiguous to subimbricate, becoming sublobulate with age, the lobules appressed; upper surface continuous, shiny, emaculate, irregularly cracked with age, moderately isidiate, the isidia initially globose, 0.1–0.3 mm in diameter and up to 0.3 mm high, soon erupting into pustulate or coarsely subsorediate masses; lower surface plane, brownish at the tips but black toward the center, moderately rhizinate, the rhizines black, 0.2–0.3 mm long.

Pycnidia and apothecia not found.

Chemistry: Stictic, constictic, norstictic (trace) and usnic acids and an unidentified fatty acid.

Type collection: Open dolerite ridges in karoo, 22 km ENE of Prince Albert on the road to Seekoeigat, elev. 1000 m, Cape Province, S. Africa, Grid 3322 AB, M. E. Hale 75115, 31 Jan. 1986 (US, holotype; PRE, isotype).

The only closely related species, X. mougeotii (Schaer.) Hale, has distinct capitate soralia and is more tightly adnate. I have not had an opportunity to revise herbarium records of X. mougeotii from S. Africa; these may well represent X. pustulifera.

Additional specimen examined. S. Africa. Cape Province: Same locality as the holotype, Hale 75116 (US); Devil's Peak, Table Mountain, Grid 3318 CD, Nash s.n. (ASU).

Xanthoparmelia rubromedulla Hale, sp. nov. Fig. 42

Thallus laxe adnatus, saxicola, 5–10 cm latus, lobis irregulariter sublinearibus, 1–1.5 mm latis, superne distincte maculatus, isidiis sorediisque destitutus, subtus planus, niger, modice rhizinosus.

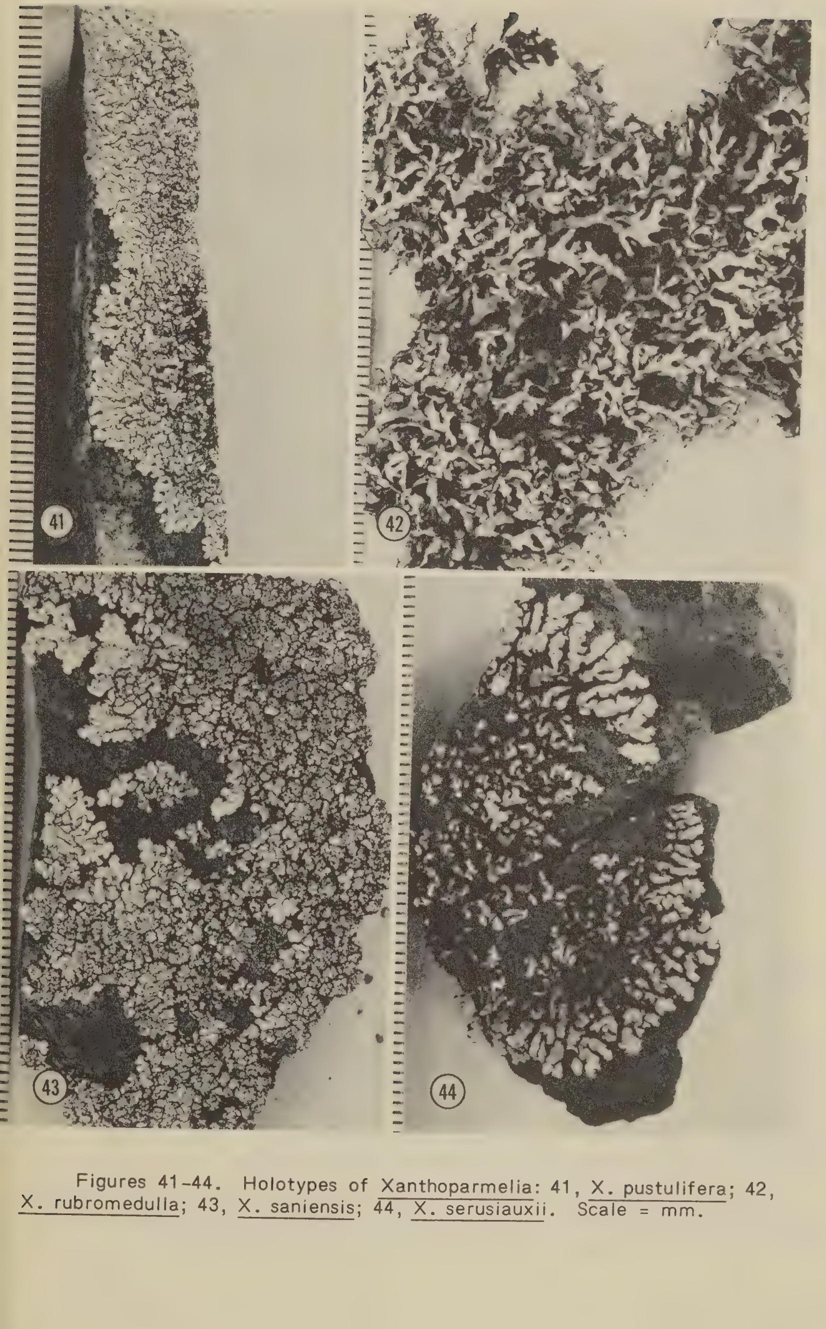
Thallus loosely adnate on rock, rather rigid and brittle, fragmenting, 5–10 cm broad, light yellowish green; lobes sublinear, 1–1.5 mm wide, dichotomously branched, subimbricate; upper surface uniformly maculate, shiny, isidia and soredia absent; lower part of medulla orange-red; lower surface plane, brown at the tips but becoming black, sparsely to moderately rhizinate, the rhizines black, rather coarse, 0.5–1 mm long.

Pycnidia sparsely developed; conidia not found. Apothecia absent.

Chemistry: Salazinic and usnic acids, skyrin.

Type collection: Sandy rock face above stream, Waaihoek Peak, elev. 1680 m, Worcester Division, Cape Province, S. Africa, Grid 3319 AD, E. Esterhuysen 22560, 12 Jan. 1954 (BOL, holotype; US, isotype).

This species has some resemblance to X. synestia (Stirt.) Hale but the lobes are more elongate, the thallus is more rigid, quite loosely adnate and pulvinate on rock, and skyrin is present in the medulla. Both X. luminosa (Elix) Hale and X. surrogata Hale (below) are more closely adnate and coriaceous with broader lobes.



Figures 41-44. Holotypes of Xanthoparmelia: 41, X. pustulifera; 42, X. rubromedulla; 43, X. saniensis; 44, X. serusiauxii. Scale = mm.

Xanthoparmelia saniensis Hale, sp. nov. Fig. 43

Thallus arcte adnatus vel fere subcrustosus, saxicola, 4-6 cm latus, lobis subirregularibus, 1-1.5 mm latis, centrum versus bullatis, superne emaculatus, isidiatus, isidiis globosis, fragilibus, subtus planus, pallide brunneus, modice rhizinosus.

Thallus tightly adnate to nearly subcrustose on doleritic rock, 4-6 cm broad, yellowish green; lobes subirregular, 1-1.5 mm wide, brown to black rimmed, contiguous to imbricate and bullate at the center; upper surface continuous, shiny, emaculate, isidiate, isidia dense, globose and basally constricted, bursting open apically, 0.1-0.3 mm in diameter, 0.1-0.3 mm high; lower part of medulla ochre; lower surface plane, pale brown tinged with ochre, moderately rhizinate, the rhizines pale brown, 0.3-0.5 mm long.

Pycnidia and apothecia lacking.

Chemistry: Hypostictic, hyposalazinic and usnic acids, another "quintaria" unknown, and skyrin.

Type collection: Exposed dolerite ledges, Sani Pass east of Customs Gate, elev. 2875 m, Lesotho, Grid 2929 CB, M. E. Hale 74031, 19 Feb. 1986 (US, holotype; PRE, isotype).

This remarkable high elevation Drakensberg species, characterized by the globose isidia and tightly adnate habit, has only one probable relative, the rare Brazilian X. kalbii Hale, another hypostictic acid-containing Xanthoparmelia, not as tightly adnate, with broader lobes and without skyrin.

Xanthoparmelia serusiauxii Hale, sp. nov. Fig. 44

Thallus adnatus, saxicola, 5-10 cm latus, lobis sublineeribus, inflatis, 1-2 mm latis, superne continuus, nitidus vel pruinosus, isidiis sorediisque destitutus, subtus planus, niger, sparse rhizinosus.

Thallus adnate to tightly adnate on rock, soft, 5-10 cm broad, dull greenish yellow and blackening at the center with age; lobes sublinear, little branched, 1-2 mm wide, appearing inflated, black-rimmed, contiguous, short laciniate at the center with age; upper surface continuous, the tips faintly reticulate-maculate, shiny or mostly dull white pruinose, convex and heavily rugose at the center; isidia and soredia absent; lower surface plane, black, dull, very sparsely rhizinate, the rhizines coarse, 0.3-0.5 mm long.

Pycnidia common; conidia not found. Apothecia lacking.

Chemistry: Lecanoric and usnic acids.

Type collection: Laguneberg Mountains, NE of Mile 72, Distr. Omaruru, S.W.A./Namibia, Grid 2114 CC, M. E. Hale 75102, 8 Jan. 1986 (US, holotype; PRE, isotype).

This is a common Xanthoparmelia in the central Namib area. It grows on large dolerite boulders and small flat pebbles in desert pavement. The lobes are sublinear, little branched, and seem inflated. The medulla is especially thick and soft. I examined the surface for epicortical pores with the scanning electron microscope. They are present but obscured by crystals of pruina except at lobe margins. The species is named in honor of Dr. Emanuel Serusiaux, the first lichenologist to collect this unusual lichen in Namibia. Related species in this unusual locality include X. evernica Hale and X. lagunebergensis Hale (above).

Additional specimens examined. S.W.A./Namibia: Same locality as the holotype, Hale 75108, 75109, 75111 (US), Nash 23303 (ASU, US); gravel flats east of Cape Cross, Grid 2114 CA, Hale 75113, 75114 (US).

Xanthoparmelia simulans Hale, sp. nov. Fig. 45

Thallus laxe adnatus, saxicola vel terricola, 5-8 cm latus, lobis linearibus, 0.5-1 mm latus, nigro-marginatis, irregulariter constrictis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, niger, sparse rhizinosus.

Thallus loosely adnate on soil, 5-8 cm broad, bright yellowish green; lobes linear, 0.5-1 mm wide, black rimmed, little branched and irregularly constricted, divaricately branched, subascending; upper surface continuous, shiny, emaculate; isidia and soredia absent; lower surface plane, black, shiny, sparsely rhizinate, the rhizines black, rather coarse, 0.5-1 mm long.

Pycnidia and apothecia lacking.

Chemistry: Stictic, constictic, cryptostictic, norstictic (trace) and usnic acids.

Type collection: Windswept ridge on S side of Swartberg Pass, Swartberg Mountains, NW of Kango Caves on Hwy R328, elev. 1800 m, Cape Province, S. Africa, Grid 3322 AC, M. E. Hale 74045, 31 Jan. 1986 (US, holotype; PRE, isotype).

This species differs from closely related X. constrictans (Nyl.) Hale in presence of the stictic acid group (in place of salazinic acid). While X. suberadicata (des Abb.) Hale from Madagascar also has stictic acid, it lacks rhizines and has uniformly linear lobes with a strongly rugose lower surface. Xanthoparmelia simulans occurs at higher elevations in southwestern Cape Province.

Additional specimens examined. S. Africa. Cape Province: Same locality as the holotype, Stirton 9535 (PRE); Platteklip Gorge to Woodhead Reservoir, Grid 3318 CD, Degelius 1A-297 (UPS, US), Hale 72032, 72035, 72045 (US); 32.7 km ESE of Citrusdal, Grid 3219 CA, Hale 72028 (US).

Xanthoparmelia skyrinifera Hale, sp. nov. Fig. 46

Thallus laxe adnatus, coriaceus, 6-12 cm latus, lobis sublinearibus, 1.5-2.5 mm latis, superne continuus vel sparse maculatus, isidiis sorediisque destitutus, medulla pro parte ochracea, subtus planus, pallide brunneus, modice rhizinosus.

Thallus loosely adnate on rocks, firm, 6-12 cm broad, bright yellowish green; lobes sublinear, 1.5-2.5 mm wide, more or less imbricate; upper surface faintly to distinctly maculate, rugose and transversely cracked with age; isidia and soredia absent; medulla ochre in the lower part; lower surface plane, pale brown with an ochre tinge but turning darker brown toward the center, sparsely to moderately rhizinate, the rhizines pale brown, 0.5-1.5 mm long, simple to furcate and apically splayed.

Pycnidia (from Hale 74094) common; conidia bifusiform, 0.5 X 5-6 µm. Apothecia lacking.

Chemistry: Protocetraric and usnic acids, skyrin.

Type collection: Low schist ridge in pasture, 15.9 km NE of Barrydale along Hwy R62, elev. ca 500 m, Cape Province, S. Africa, Grid 3321 DD, M. E. Hale 74040, 2 Feb. 1986 (US, holotype; PRE, isotype).

This unique lichen from southern Cape Province is characterized by the loosely adnate habit, pale brown, moderately rhizinate lower surface and chemistry. Another species with protocetraric acid and skyrin, X. subcolorata Hale (below), has a maculate surface, rugose eroding lower surface and sparse rhizines.

Additional specimens examined. S. Africa. Cape Province: Same locality as the holotype, Hale 74102, 74105 (US); 23 km SW of Ladismith, Grid 3321 CA, Hale 74094, 74095 (US).

Xanthoparmelia stenosporonica Hale, sp. nov. Fig. 47

Thallus arcte adnatus, saxicola, 1-2 cm latus, lobis sublinearibus, 0.2-0.5 mm latis, brevibus, nigromarginatis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, niger, modice rhizinosus.

Thallus tightly adnate on rock, 1-2 cm broad, light yellowish green; lobes sublinear to subirregular, 0.2-0.5 mm wide, short, contiguous to imbricate, black rimmed; upper surface continuous, shiny, emaculate; isidia and soredia absent; lower surface plane, shiny, black, moderately rhizinate, the rhizines black, 0.1-0.2 mm long.

Pycnidia and apothecia lacking.

Chemistry: Stenosporonic, colensoic and usnic acids.

Type collection: Summit of Swartberg Pass on Hwy R328, elev. 1585 m, Cape Province, S. Africa, Grid 3322 AC, M. E. Hale 72117, 31 Jan. 1986 (US, holotype; PRE, isotype).

This inconspicuous species grows intermixed with X. endochromatica Hale (above) in an exposed, high elevation habitat in southwestern Cape Province. Stenosporonic acid has not previously been reported in the genus.

Additional specimen examined. S. Africa. Cape Province: Same locality as the holotype, Hale 72082 (US).

Xanthoparmelia subcolorata Hale, sp. nov. Fig. 48

Thallus adnatus vel laxe adnatus, saxicola, 6-8 cm latus, lobis sublinearibus, subadscendentibus, 2-4 mm latis, superne maculatus, isidiis sorediisque destitutus, medulla pro parte ochracea, subtus planus, rugosus, pallide brunneus, sparsissime rhizinosus.

Thallus adnate to loosely attached on rock, forming discrete, nearly umbilicate colonies, 6-8 cm broad, dark yellowish green; lobes sublinear, 2-4 mm wide, crowded and imbricate, subascending; upper surface moderately to strongly maculate, shiny, deeply transversely cracked; isidia and soredia absent; lower part of medulla ochre; lower surface plane, pale or darker brown with ochre spots, blackening toward the tips, strongly rugose and in part eroding with age, rhizines absent or very sparse, brown, coarse, to 1 mm long.

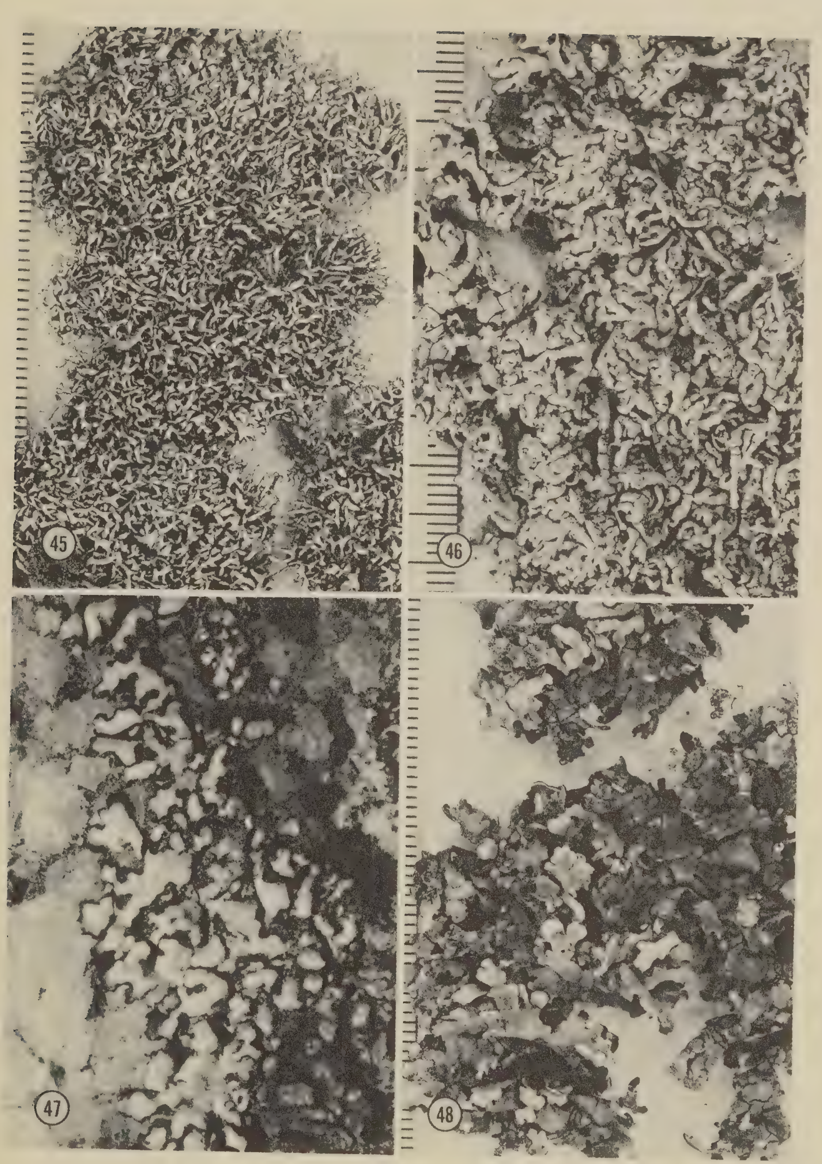
Pycnidia common; conidia bifusiform, 0.5 X 5-6 µm. Apothecia common, adnate, 5-10 mm in diameter; hymenium 40-45 µm; spores 5-6 X 10-12 µm.

Chemistry: Protocetraric and usnic acids, skyrin.

Type collection: Sloping sandstone boulders in Fynbos, 19.9 km NW of Kango Caves on Swartberg Pass Road, elev. ca 1100 m, Cape Province, S. Africa, Grid 3322 AC, M. E. Hale 73014, 31 Jan. 1986 (US, holotype; PRE, isotype).

This loosely adnate, almost umbilicate lichen resembles X. denudata Hale (see above), which has a similar lower surface and skyrin but differs in having salazinic acid as the main component and narrower lobes. It also falls close to X. austroafricana (Stirt.) Hale, which has a more typically foliose thallus and lacks skyrin and distinct maculae. It has a typical Cape-Namaqualand distribution with a disjunct record in Transvaal.

Additional specimens examined. Cape Province: 1 km S of Nuwerus on Hwy 363, Grid 3118 AB, Hale, 72107 (US); 44 km N of Vanrhynsdorp, Grid 3118 BC, Hale 73115, 75116, 75117 (US); 32.7 km ESE of Citrusdal, Grid



Figures 45-48. Holotypes of Xanthoparmelia: 45, X. simulans; 46, X. skyrinifera; 47, X. stenosporonica (enlarged X10); 48, X. subcolorata. Scale = mm.

3219 CA, Hale 72088 (US); summit of Bainskloof on Hwy N1, Grid 3319 CA, Hale 72104, 72106 (US), Sipman 20229 (B); Anenouspas, Grid 2917 BA, Hale 73131 (US); 26.4 km E of Ladismith, Grid 3321 AD, Hale 73057 (US); Kruisrivier, Grid 3321 BB, Hale 73056 (US). Transvaal: Lejuma Summit, Soutpansberg Mountains, Grid 2329 AB, Sipman 19871 (B).

Xanthoparmelia subcrustosa Hale, sp. nov. Fig. 49

Thallus arcte adnatus, subcrustosus, saxicola, 2–3 cm latus, lobis subirregularibus, 0.6–1.0 mm latis, centrum versus areolato-bullatis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, pallide brunneus, modice rhizinosus.

Thallus subcrustose to tightly adnate on rocks, 2–3 cm broad, pale yellowish green; lobes subirregular, 0.6–1.0 mm wide, bullate-areolate in the center; upper surface continuous, shiny or at times pruinose, emaculate, transversely cracked; isidia and soredia absent; lower surface plane, pale brown, moderately rhizinate, the rhizines pale brown, 0.3–0.5 mm long.

Pycnidia common; conidia bifusiform, 0.5 X 5–6 µm. Apothecia poorly developed, adnate, 1 mm in diameter; hymenium 42–45 µm; spores 6 X 8–9 µm.

Chemistry: Salazinic, norstictic, connorstictic and usnic acids, chalybaeizans unknown.

Type collection: On granite boulders in karoo, 8.3 km E of Garies on Studerspas Road, elev. 900 m, Cape Province, S. Africa, Grid 3018 AC, M. E. Hale 73016, 26 Jan. 1986 (US, holotype; PRE, isotype).

Xanthoparmelia subcrustosa is unique among subcrustose species in chemistry. It is widely distributed in southern Cape Province.

Additional specimens examined. S. Africa. Cape Province: Ceres Nature Reserve SW of Ceres, Grid 3319 AD, Hale 72110 (US); 78.6 km S of Sutherland, Grid 3220 DC, Hale 73122 (US); 33.8 km W of Dordrecht, Grid 3126 BC, Hale 73119, 73120 (US).

Xanthoparmelia subnigra Hale, sp. nov. Fig. 50

Thallus adnatus vel arcte adnatus, 4–6 cm latus, lobis sublinearibus, 1–2 mm latis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, niger, modice rhizinosus.

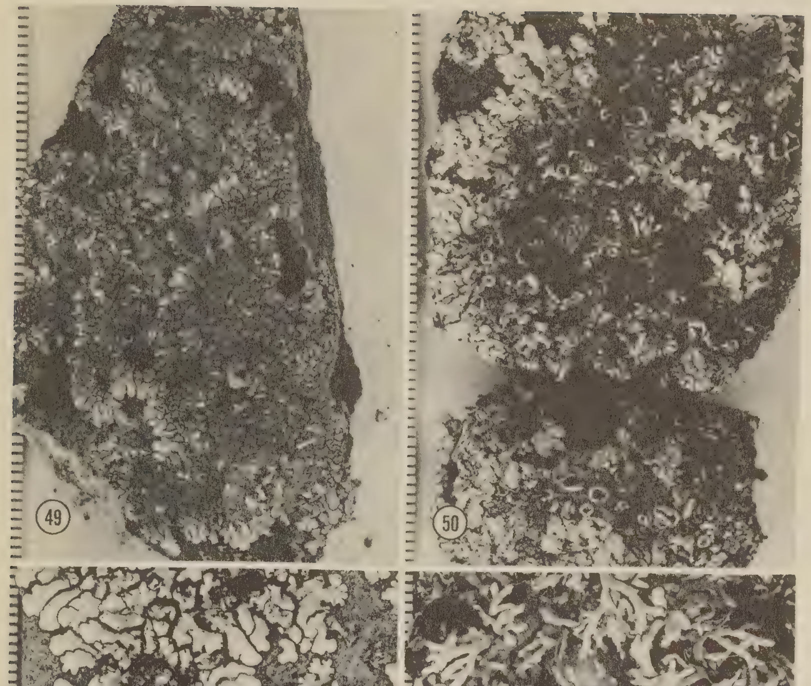
Thallus adnate to tightly adnate on rocks, 4–6 cm broad, light yellowish green; lobes sublinear to subirregular, 1–2 mm wide, contiguous; upper surface continuous, shiny, emaculate; isidia and soredia absent; lower surface plane, black, sparsely to moderately rhizinate, the rhizines black, 0.5–1 mm long.

Pycnidia common; conidia bifusiform, 0.5 X 6–7 µm. Apothecia numerous, adnate, 1–2 mm in diameter; hymenium 44–48 µm; spores 6–7 X 8–10 µm.

Chemistry: Dehydroconstipatic (major), pertusaric (major), protoconstipatic (trace), constipatic (trace) and usnic acid in addition to other unidentified fatty acids (determined by J. Johnston).

Type collection: Small sandstone outcrops in pasture, summit of Long Tom Pass on S side of Hwy R37, Farm De Kuiten 205, elev. 2140 m, Lydenburg, Transvaal, S. Africa, Grid 2430 BA, M. E. Hale 72026, 16 Jan. 1986 (US, holotype; PRE, isotype).

No other constipatic acid-containing species of Xanthoparmelia have a black lower surface, excepting X. aliphatica Hale (above), which is a much larger, loosely adnate lichen. A comparable species with a pale lower surface is the widespread X. subdecipiens (Vain.) Hale. A



Figures 49-52. Holotypes of *Xanthoparmelia*: 49, *X. subcrustosa*; 50, *X. subnigra*; 51, *X. subochracea*; 52, *X. subruginosa*. Scale = mm.

presumptive isidiate morphotype, X. transvaalensis Hale, Nash & Elix (below), occurs in the same locality.

Additional specimen examined. S. Africa. Transvaal: Same locality as the holotype, Nash 23438 (ASU, US).

Xanthoparmelia subochracea Hale, sp. nov. Fig. 51

Thallus adnatus, saxicola, 3-6 cm latus, lobis subirregularibus, 1.5-2.5 mm latis, superne emaculatus, convexus, isidiis sorediisque destitutus, medulla pro parte ochracea, subtus planus, brunneus, modice rhizinosus.

Thallus rather closely adnate on rock, 3-6 cm broad, bright yellowish green; lobes subirregular, 1.5-2.5 mm wide, apically rotund, black rimmed, contiguous; upper surface continuous, shiny, emaculate, convex, bullate toward the center; isidia and soredia absent; medulla ochre in the lower part; lower surface plane, brown to dark brown, sparsely to moderately rhizinate, the rhizines brown, coarse, ca 0.5 mm long.

Pycnidia common; conidia bifusiform, 5-6 µm. Apothecia poorly developed, adnate, 1-2.5 mm in diameter; hymenium ca 35 µm; spores 5-6 X 9 µm.

Chemistry: Protocetraric and usnic acids, skyrin.

Type collection: Exfoliating granite outcrops in karoo, 78.6 km S of Sutherland on Hwy R354, elev. ca 900 m, Cape Province, S. Africa, Grid 3220 DC, M. E. Hale 73017, 29 Jan. 1986 (US, holotype; PRE, isotype).

This adnate conspersoid lichen may be related to X. dichromatica (Hale) Hale, which is more loosely adnate and contains purplish anthraquinone pigments. Xanthoparmelia tumidosa Hale (below) has convex, more closely adnate lobes and lacks skyrin.

Xanthoparmelia subruginosa Hale, sp. nov. Fig. 52

Thallus laxe adnatus, saxicola, 6-10 cm latus, lobis sublinearibus, elongatis, 0.5-1.5 mm latis, superne emaculatus vel sparse maculatus, isidiis sorediisque destitutus, subtus planus, rugosus, niger, rhizinis nullis.

Thallus loosely adnate on flat rocks, 6-10 cm broad, bright yellowish green; lobes sublinear, dichotomously branched, 0.5-1.5 mm wide, divaricate to subimbricate; upper surface continuous, shiny, emaculate or weakly maculate on some older lobes, transversely cracked with age; isidia and soredia absent; lower surface plane, smooth to rugose, black, the tips with a yellowish rim, rhizines absent.

Pycnidia and apothecia absent.

Chemistry: Stictic, constictic and usnic acids.

Type collection: Flat sandstone exposures back from cliff, Oribi Gorge Nature Reserve, elev. 300 m, Natal, S. Africa, Grid 3030 CB, M. E. Hale 74042, 3 Feb. 1986 (US, holotype; PRE, isotype).

Another nonisidiate stictic acid-containing species which lacks rhizines, X. albomaculata Hale, is generally more adnate, has shorter, more subirregular lobes, a coriaceous thallus and distinct maculae on the surface. It occurs at higher elevations in eastern Transvaal. Xanthoparmelia suberadicata (des Abb.) Hale from Madagaascar has narrower, more elongate, divaricate lobes, usually not more than 1 mm wide.

Additional specimens examined. S. Africa. Natal: Same locality as the holotype, Hale 74018, 74019 (US).

Xanthoparmelia surrogata Hale, sp. nov. Fig. 53

Thallus adnatus, saxicola, 6-10 cm latus, coriaceus, lobis sublinearibus, 1-2 mm latis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, modice rhizinosus.

Thallus adnate to loosely adnate on rock, rather leathery, 6-10 cm broad, dull yellowish green; lobes sublinear-elongate, 1-2 mm wide, separate to subimbricate; surface continuous, shiny, emaculate, becoming finely fissured toward the center; isidia and soredia absent; lower part of medulla orange red; lower surface plane, black, shiny, moderately rhizinate, the rhizines black, 0.5-1 mm long.

Pycnidia common; conidia bifusiform, 0.5 X 5-6 µm. Apothecia not found.

Chemistry: Salazinic and usnic acids, skyrin.

Type collection: Large flat Table Mountain sandstone boulder in Fynbos, trail above Woodhead Reservoir (to Platteklip Gorge), Table Mountain Nature Reserve, elev. 800 m, Cape Province, S. Africa, Grid 3318 CD, M. E. Hale 72084, 23 Jan. 1986 (US, holotype; PRE, isotype).

Xanthoparmelia surrogata differs from X. luminosa (Elix) Hale, the only other species with this chemistry and a black lower surface, in having narrower, sublinear lobes and a leathery texture. Actually X. luminosa occurs at two localities in southwestern Cape Province.

Xanthoparmelia tablensis Hale, Nash and Elix, sp. nov. Fig. 54

Thallus laxe adnatus, saxicola, 6-10 cm latus, lobis sublinearibus, 0.6-1.5 mm latis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, niger, modice rhizinosus.

Thallus loosely adnate on rocks, 6-10 cm broad, bright yellowish green; lobes sublinear, elongated and little branched, 0.6-1.5 mm wide, becoming laciniate, imbricate; upper surface continuous, emaculate; isidia and soredia lacking; lower surface plane, black, sparsely to moderately rhizinate, the rhizines black, 0.5-1 mm long, simple.

Pycnidia poorly developed; conidia bifusiform, 0.5 X 5-6 µm. Apothecia adnate to substipitate, 1-3 mm in diameter; hymenium 45-50 µm; spores 6-7 X 9-11 µm (data from Nash s.n.).

Chemistry: Hypoprotocetraric, 4-O-demethylnotatic and usnic acids and several unidentified minor components.

Type collection: Large sandstone ledge in dense Fynbos, trail from Platteklip Gorge to Woodhead Reservoir, Table Mountain Nature Reserve, elev. 1000 m, Cape Province, S. Africa, Grid 3318 CD, M. E. Hale 72033, 23 Jan. 1986 (US. Holotype).

The only other loosely adnate, hypoprotocetraric acid-containing species is X. hypoprotocetrarica (Kurok. & Elix) Hale, a common effigurate-maculate lichen in S. Africa and Australia. The present species is externally close to X. tasmanica (Hook. & Tayl.) Hale, which is a larger lichen with salazinic acid. It has only been found on Table Mountain.

Additional specimen examined. S. Africa. Cape Province: Same locality as the holotype, Hale 72036 (US); Devil's Peak, Table Mountain, Grid 3318 CD, Nash s.n. (ASU).

Xanthoparmelia terricola Hale, Nash and Elix, sp. nov. Fig. 55

Thallus laxe adnatus, terricola, 6-15 cm latus, lobis sublinearibus, 1-1.5 mm latis, superne emaculatus, isidiis sorediisque destitutus, subtus planus, brunneus, modice rhizinosus.

Thallus adnate to loosely attached on rocks, pebbles and soil, often with the same thallus extending from soil to adjacent rocks, 6–15 cm broad, rather firm, yellowish green but darkening with age at the center; lobes sublinear, 1–1.5 mm wide, dichotomously branched, contiguous to imbricate; upper surface continuous, shiny, emaculate, transversely cracked and somewhat rugose with age; isidia and soredia absent; lower surface plane, brown to dark brown, moderately rhizinate, the rhizines brown, 0.5–1 mm long, simple or furcate with white tips when young.

Pycnidia common; conidia bifusiform, 0.5 X 5–6 µm. Apothecia commonly developed, adnate, 3–8 mm in diameter; hymenium 40–45 µm; spores 5–6 X 9–10 µm.

Chemistry: Salazinic, consalazinic, norstictic (trace), protocetraric (trace) and usnic acids (determined by T. Nash, J. Elix and J. Johnston).

Type collection: On soil and pebbles in area of flat sandstone exposures, top of Brandwagsrot, Golden Gate National Park, elev. ca 1900 m, Orange Free State, S. Africa, Grid 2828 BC, M. E. Hale 74036, 11 Feb. 1986 (US, holotype; PRE, isotype).

This is the commonest soil-inhabiting lichen at higher elevations in the Drakensberg escarpment. It has rather uniform, sublinear lobes with a brown to dark brown lower surface, characters which distinguish it from X. taractica (Kremplh.) Hale.

Additional specimens examined. S. Africa. Orange Free State: Same locality as the holotype, Hale, 74000, 74005, 74007, 74008, 74009, 74010, 74026, 74037, 74050 (US). Transvaal: Long Tom Pass on Hwy R37, Grid 2430 BA, Hale 72046 (US); Mt. Sheba Nature Reserve, Grid 2430 DC, Hale 72050 (US), Nash 23417, 23418 (ASU). Lesotho: Sani Pass, Grid 2929 CB, Hale 74004, 74006, 74013, 74028, 74033. Natal: Witsieshoek Pass, Grid 2828 DD, Hale 74011, 74012, 74014, 74016, 74025, 74027 (US).

Xanthoparmelia thamnolica Hale, sp. nov. Fig. 56

Thallus adnatus, saxicola, 5–8 cm latus, lobis subirregularibus, brevibus, 1.3–2.5 mm latis, superne emaculatus, isidiatus, isidiis cylindricis, subtus planus, niger, modice rhizinosus.

Thallus adnate on rocks, easily breaking apart, 5–8 cm broad, dark yellowish green; lobes subirregular to sublinear, 1.3–2.5 mm wide, imbricate; upper surface continuous, shiny, emaculate, isidiate, the isidia becoming dense with age, cylindrical, simple to branched, 0.08–0.1 mm in diameter, 0.1–0.3 mm high; lower surface plane, black with a dark brown zone at the tips, moderately to densely rhizinate, the rhizines black, 0.5–2 mm long, simple to furcate.

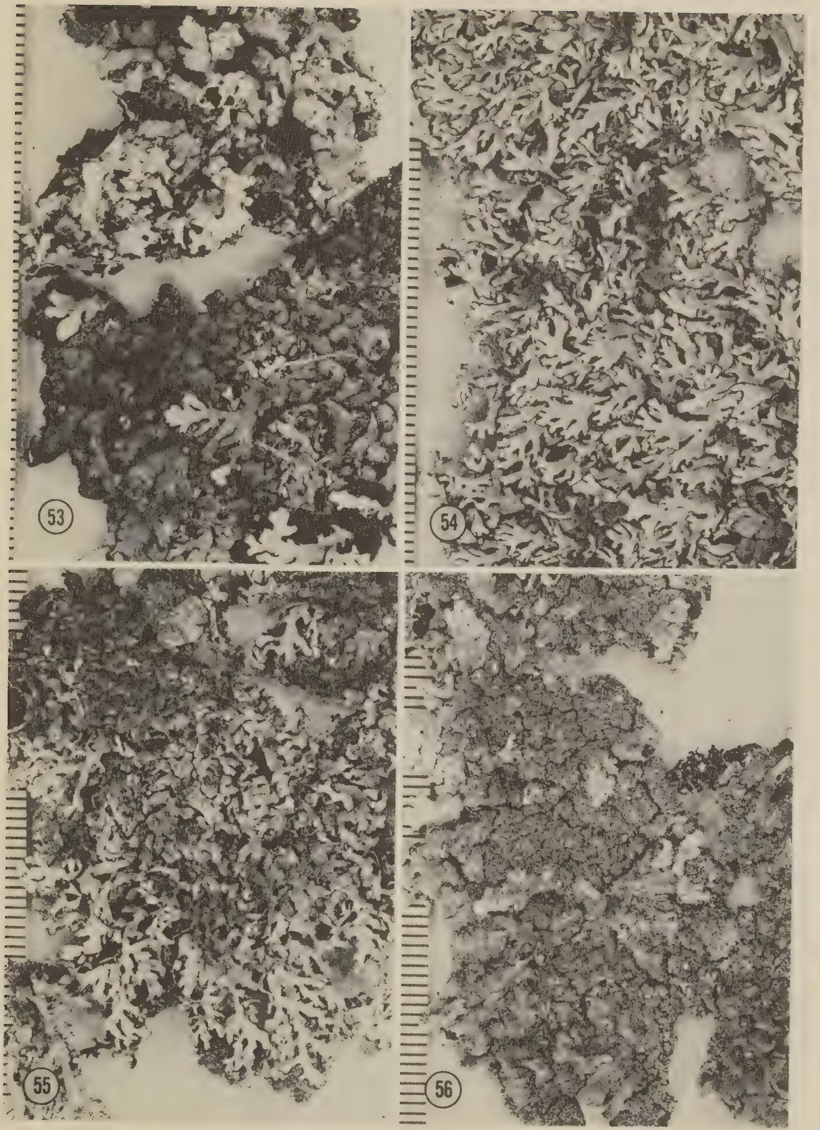
Pycnidia and apothecia not seen.

Chemistry: Thamnolic and usnic acids.

Type collection: On large sandstone boulders in pasture, 25 km S of Clanwilliam along Hwy N7, elev. ca 300 m, Cape Province, S. Africa, Grid 3218 DD, M. E. Hale 72034, 25 Jan. 1986 (US, holotype; PRE, isotype).

Only one other Xanthoparmelia species contains thamnolic acid (always with squamatic acid, lacking in X. thamnolica), X. cedrus-montana Brusse, a member of the effigurate-maculate X. hypoleia group. Superficially X. thamnolica would seem to be a rather large X. conspersa (Ach.) Hale, a common species with stictic acid, which also occurs in S. Africa. This species is highly restricted to the Clanwilliam area in southern Namaqualand.

Additional specimens examined. S. Africa. Cape Province: Same locality as the holotype, Hale 72040 (US); 36.4 km S of Clanwilliam, Grid 3218 DD, Hale 72025, 72039 (US); Witelskloof, Grid 3218 BD, Brusse



Figures 53-56. Holotypes of *Xanthoparmelia*: 53, *X. surrogata*; 54, *X. tablensis*; 55, *X. terricola*; 56, *X. thamnolica*. Scale = mm.

3092 (PRE); Versveld Pass, Grid 3218 DC, Brusse 2937 (PRE); 7 km W of Tulbagh, Grid 3319 AC, Brusse 2714 (PRE); 32.7 km ESE of Citrusdal, Grid 3219 CA, Hale 72042 (US).

Xanthoparmelia toninioides Hale, sp. nov. Fig. 57

Thallus adnatus, saxicola, 4-6 cm latus, lobis subirregularibus, 1-2 mm latis, centrum versus valde bullatis, superne emaculatus, pruinosus, isidiis sorediisque destitutus, subtus planus, ambitu niger, centro pallide brunneus, modice rhizinosus.

Thallus adnate to tightly adnate on rocks, 4-6 cm broad, light yellow green; lobes subirregular, 1-2 mm wide, short, contiguous, becoming strongly bullate at the center; upper surface continuous, dull, becoming densely pruinose; isidia and soredia absent; lower surface plane to concave, blackish toward the tips but brown to pale brown toward the center, moderately to densely rhizinate, the rhizines black or brown, 0.3-0.5 mm long.

Pycnidia and apothecia not found.

Chemistry: Hypoprotocetraric, 4-O-demethylnotatic and usnic acids.

Type collection: Sloping granite domes in karoo, 1 km east of Springbok on north side of Hwy R64, elev. 1100 m, Cape Province, S. Africa, Grid 2917 DB, M. E. Hale 72086, 27 Jan. 1986 (US, holotype; PRE, isotype).

The conspicuous bullate folds of thallus are filled with a flocculent medulla. It is related to X. encrustans (Hale) Hale, a subcrustose species, and probably confined to upper Namaqualand.

Additional specimen examined. S. Africa. Cape Province: Same locality as the holotype, Hale 72086 (US).

Xanthoparmelia transvaalensis Hale, Nash and Elix, sp. nov. Fig. 58

Thallus adnatus, saxicola, 6-8 cm latus, lobis subirregularibus, 1-2 mm latis, margine laciniatis, superne emaculatus, isidiatus, isidiis globosis, densis, subtus planus, nigricans, modice rhizinosus.

Thallus adnate on rock, 6-8 cm broad, darkish yellow green; lobes subirregular to sublinear, 1-2 mm wide, imbricate with small marginal laciniae ca 0.5 mm wide; upper surface continuous, shiny, emaculate, isidiate, isidia dense and crowded, globose, basally constricted, mostly unbranched, breaking off apically, 0.15-0.18 mm in diameter, 0.15-0.2 mm high; lower surface plane, brown to black, sparsely to moderately rhizinate, the rhizines brown or blackening, 0.5-1 mm long, simple.

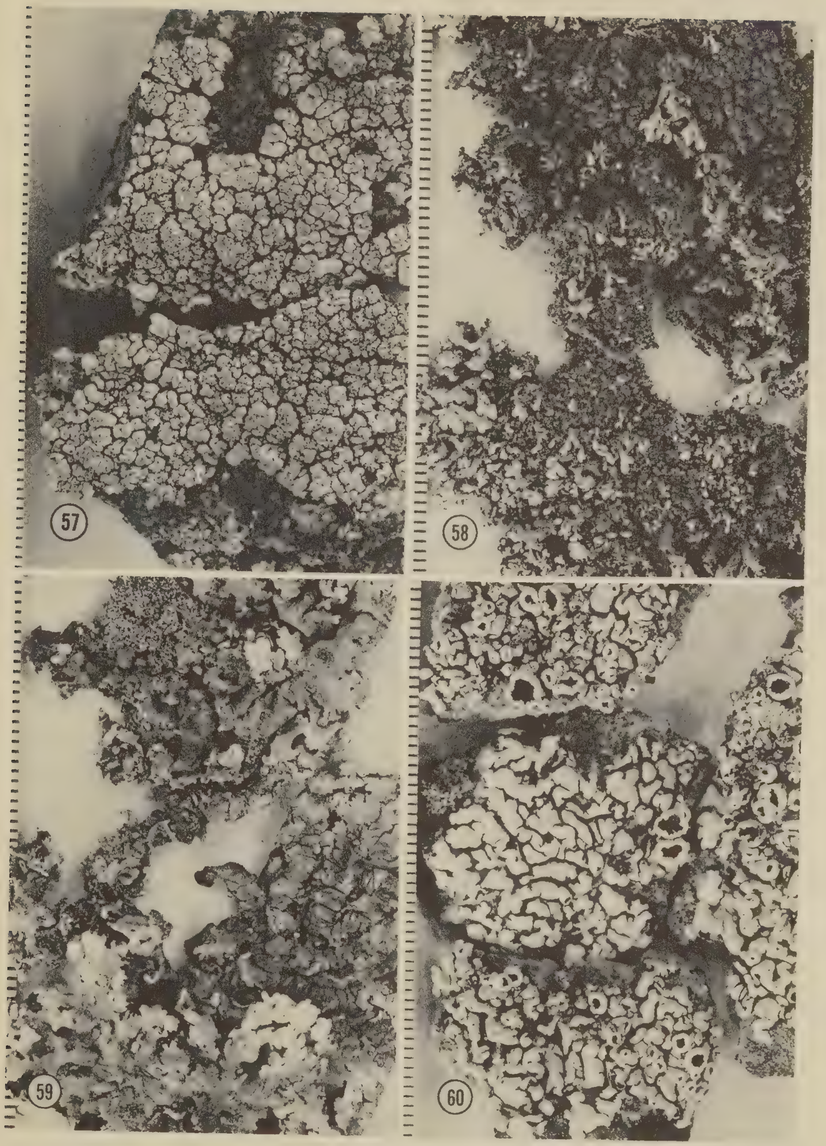
Pycnidia lacking. Apothecia rare, substipitate, 2-5 mm in diameter; hymenium 45 µm; spores poorly developed, 5 X 7-8 µm (data from Nash 23441).

Chemistry: Dehydroconstipatic (major), pertusaric (major), constipatic (trace), protoconstipatic (trace) and usnic acids with other unidentified fatty acids (same as in X. subdecipiens (Vain.) Hale) (determined by J. Johnston).

Type collection: On sandstone outcrop in pasture, summit of Long Tom Pass, Farm De Kuiten 205, S side of Hwy R37, elev. 2140 m, Lydenburg, Transvaal, S. Africa, Grid 2430 BA, M. E. Hale 72038, 16 Jan. 1986 (US, holotype; PRE, isotype).

This species has the same chemistry and black lower surface as X. subnigra Hale, another species collected so far only at Long Tom Pass in the Drakensbergs and perhaps representing the nonisidiate morphotype.

Additional specimens examined. S. Africa. Same locality as the holotype, Hale 72027 (US), Nash 23441 (ASU).



Figures 57-60. Holotypes of *Xanthoparmelia*: 57, *X. toninioides*; 58, *X. transvaalensis*; 59, *X. treurensis*; 60, *X. tumidosa*. Scale = mm.

Xanthoparmelia treurensis Hale, Nash and Elix, sp. nov. Fig. 59

Thallus adnatus vel laxe adnatus, coriaceus, saxicola, 6–8 cm latus, lobis sublinearibus, 2–5 mm latis, superne sparse maculatus, isidiatus, isidiis cylindricis, subtus planus, rugosus, niger, rhizinis nullis.

Thallus adnate to loosely adnate on rocks, firm, 6–8 cm broad, darkish yellowish green; lobes sublinear, 2–5 mm wide, contiguous; upper surface continuous to weakly or strongly maculate in older parts, shiny, transversely cracked, isidiate, the isidia moderately developed, cylindrical, simple to coralloid branched, 0.15–0.2 mm in diameter, 0.5–2 mm high; lower surface plane, rugose, rhizines absent or very sparsely developed.

Pycnidia and apothecia lacking.

Chemistry: Stictic, constictic, cryptostictic, norstictic (trace), connorstictic (trace), constipatic and usnic acids (determined by T. Nash, J. Elix and J. Johnston).

Type collection: On sandstone in coppice area, Treur River near Bourkes Luck, elev. 1200 m, Pilgrims Rest, Transvaal, S. Africa, Grid 2430 DB, M. E. Hale 72037, 14 Jan. 1986 (US, holotype; PRE, isotype).

This species appears to be the isidiate morph of X. albomaculata Hale, which has more distinct maculae. It is known only from two localities in Transvaal but has probably been overlooked in the escarpment area.

Additional specimens examined. S. Africa. Transvaal: Same locality as the holotype, Hale 72044, 72048, 72049 (US), Sipman 19912 (B); Lejuma Summit, Soutpansberg Mountains, Grid 2329 AB, Sipman 19873 (B).

Xanthoparmelia tumidosa Hale, sp. nov. Fig. 60

Thallus adnatus, saxicola, 3–6 cm latus, lobis sublinearibus, brevibus, 1.5–2.0 mm latis, centrum versus congestis, bullatis, superne emaculatus, convexus, isidiis sorediisque destitutus, subtus planus, brunneus, modice rhizinosus.

Thallus adnate on rocks, leathery, 3–6 cm broad, bright yellowish green; lobes short, sublinear, 1.5–2.0 mm wide, little branched, contiguous but becoming crowded and bullate at the center; upper surface continuous, dull, emaculate, convex-bullate; isidia and soredia absent; lower surface plane to somewhat grooved, pale to darker brown, sparsely to moderately rhizinate, the rhizines pale brown, ca 0.5 mm long, coarse, unbranched.

Pycnidia common; conidia bifusiform, 0.5 X 5–6 µm. Apothecia numerous, adnate, 1.5–2.5 mm in diameter, the rim rolling inward; hymenium 55–60 µm; spores 5–6 X 9–10 µm.

Chemistry: Protocetraric and usnic acids.

Type collection: Large exposed sandstone ledge in pasture, 1 km S of Nuwerus on Hwy R363, E of N7, elev. ca 500 m, Cape Province, S. Africa, Grid 3118 AB, M. E. Hale 72027, 26 Jan. 1986 (US, holotype; PRE, isotype).

The coriaceous, convex, adnate, almost inflated lobes distinguish this Namaqualand-southwestern Cape lichen. There are no close relatives with protocetraric acid.

Additional specimens examined. S. Africa. Cape Province: 1 km E of Springbok, Grid 2917 DB, Hale 72047 (US); 8.3 km E of Garies, Grid 3018 AC, Hale 73108, 73110 (US); 44 km N of Vanrhynsdorp, Grid 3118 BC, Hale 73010, 73109, 73112 (US); 19.5 km NNW of Vanrhynsdorp, Grid 3118 BC, Hale 73111 (US); Kruisrivier, Grid 3321 BB, Hale 73011 (US); Seven Weeks Poort, Grid 3321 AD, Brusse 3587 (PRE).

Xanthoparmelia viridis Hale, sp. nov. Fig. 61

Thallus laxe adnatus, saxicola, 6–10 cm latus, lobis subirregularibus, 1.2–2.5 mm latis, superne maculatus, isidiis sorediisque destitutus, subtus planus, brunneus vel nigricans, modice rhizinosus.

Thallus adnate to loosely adnate on rock, 6–10 cm broad, greenish yellow; lobes subirregular to sublinear, 1.2–2.5 mm wide, imbricate, irregularly laciniate; upper surface faintly to distinctly maculate, shiny; isidia and soredia absent; lower surface plane, brown but blackening at the center, uniformly moderately rhizinate, the rhizines black, 1–1.5 mm long, simple.

Pycnidia common; conidia bifusiform, 0.5 X 6–7 µm. Apothecia numerous, adnate, 2–4 mm in diameter; hymenium 40–45 µm; spores 5–7 X 9–10 µm.

Chemistry: Fumarprotocetraric, succinprotocetraric and usnic acids.

Type collection: Schist ledges on hillside, Karoo Botanical Garden, Worcester, elev. 300 m, Cape Province, S. Africa, Grid 3319 CC, M. E. Hale 74023, 20 Jan. 1986 (US, holotype; PRE, isotype).

There is only one closely related species with fumarprotocetraric acid, X. nuwarensis Hale (above), a Namaqualand lichen which is brown below. Xanthoparmelia viridis may represent a chemotype of X. synestia (Stirt.) Hale, a more widely distributed species in southwestern Cape Province with salazinic acid.

Additional specimen examined. S. Africa. Cape Province: Kirstenbosch Botanical Garden, Grid 3318 DC, Hale 72103 (US).

Xanthoparmelia wesselsii Hale, sp. nov. Fig. 62

Thallus laxe adnatus, terricola, tenuis, 4–7 cm latus, lobis linearibus, elongatis, 0.5–1.5 mm latis, vix contrictis, apice subteretibus, superne emaculatus, isidiis sorediisque destitutus, subtus planus, brunneus, sparse rhizinosus.

Thallus loosely adnate on soil and humus, easily breaking apart, 4–7 cm broad; lobes linear, elongate, 0.5–1.5 mm wide, sometimes weakly constricted, dichotomously branched, separate to divaricately imbricate, the ultimate branches becoming terete, subascending; upper surface continuous, shiny, emaculate; isidia and soredia absent; lower surface plane to somewhat convoluted, shiny, light to darker brown in flaring parts of lobes, interrupted by concolorous constricted parts, sparsely rhizinate, the rhizines brown to dark brown, 0.5–1 mm long.

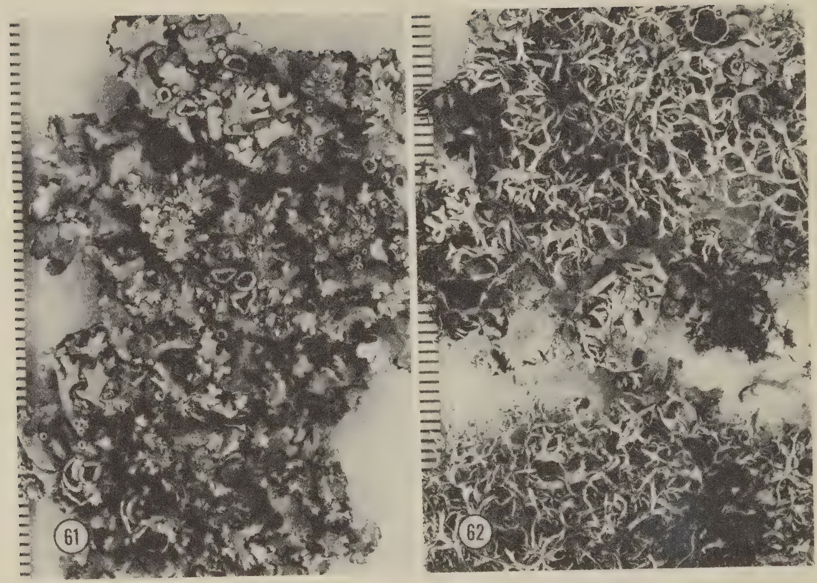
Pycnidia not well developed; conidia not seen. Apothecia adnate, 3–4 mm in diameter; hymenium 42–45 µm; spores 5–6 X 9–10 µm.

Chemistry: Salazinic, consalazinic and usnic acids.

Type collection: On soil among small sandstone outcrops in pasture, summit of Long Tom Pass on S side of Hwy R37, Farm De Kuiten, Lydenburg, elev. 2140 m, Transvaal, S. Africa, Grid 2430 BA, M. E. Hale 72043, 16 Jan. 1986 (US, holotype; PRE, isotype).

This soil-inhabiting lichen from higher elevations in the Drakensbergs has a lower surface consisting of flattened, flaring light brown parts a few mm long and intervening constricted areas concolorous with the upper surface. Another terricolous lichen in the Drakensbergs, X. terricola Hale, Nash & Elix, has broader, more appressed lobes. This species is named in honor of Dirk Wessels.

Additional specimens examined. S. Africa. Transvaal: Same locality as the holotype, Hale 72017, 72018, 72019 (US), Sipman 200781 (B); Mt. Anderson, Leighton 3272 (BOL); 14 km N of Dullstroom, Grid 2530 AC, Drews CH4359 (PRE).



Figures 61, 62. Holotypes of *Xanthoparmelia*: 61, *X. viridis*; 62, *X. wesselsii*. Scale = mm.

MYCOTAXON

Vol. XXVI, pp. 611-616 October-December 1986

NEW SPECIES OF RELICINA (LICHENIZED ASCOMYCOTINA) FROM AUSTRALASIA

JOHN A. ELIX and JEN JOHNSTON

Department of Chemistry, The Faculties, Australian National University, GPO Box 4, Canberra, ACT, 2601, Australia

ABSTRACT : The species, *Relicina agglutinata* Elix&Johnston and *Relicina niuginiensis* Elix&Johnston from Papua New Guinea, *Relicina conglutinata* Elix&Johnston, *Relicina demethylbarbatica* Elix&Johnston and *Relicina filsonii* Elix&Johnston from Australia, and *Relicia fijiensis* Elix&Johnston from Fiji are described as new. In addition the new combination, *Relicina butleri* (Elix) Elix&Johnston is made.

Introdution

The lichen genus *Relicina* Hale, a segregate of *Parmelia* Acharius sens.lat., was erected by Hale (Hale 1974) to accommodate those species with narrow, adnate lobes, marginal bulbate cilia and usnic acid in the upper cortex. *Relicina* is characterised further by an upper cortex consisting of a basic palisade plectenchyma with a pored epicortex (Hale 1973) and short, bifusiform conidia. In a subsequent monograph Hale (Hale 1975) considered *Relicina* to comprise of 24 species with the major centre of distribution being in south-east Asia and Indonesia. At that time a total of seven species were known to occur in the Australasian region and a further twelve have been recognised since (Elix & Stevens 1979; Kashiwadani 1975; Kurokawa 1979; Stevens 1981), but we now wish to describe a further six new species.

Throughout the present work chemical constituents were identified by thin layer chromatography (Culberson 1972; Culberson & Johnson 1982), high performance liquid chromatography (Lumbsch & Elix 1985) and comparison with authentic samples.

Relicina agglutinata Elix & Johnston, sp. nov. Fig.1

Species thallo ut in *Relicina sublanea* simili sed ab hac specie acido barbatico et acido 4-O-demethylbarbatico continens differt.

Type. Papua New Guinea. Milne Bay Province. On tree branch in lowland forest, Sagarai, between Wegulani and Badili Rivers, 10°24'S. 150°17'E, 40m, *R.Kumei* 136 pr.p., 16.i.1985 ; CBG-holotype.

Thallus foliose, corticolous, loosely adnate on bark, pale yellow-green to yellow-brown, to 8cm in diameter; *lobes* continuous and sublinear to linear-elongate and separate, 1.0-2.0(-3.0)mm wide, barely or not imbricate, dichotomously or subdichotomously divided, the margins bulbate ciliate, *cilia* sparse, black, inflated and becoming globose at the base but paler and often developing agglutinated hyphae towards the apices, up to 2.0mm long. *Upper surface* more or less convex, continuous, dull, weakly maculate, lacking soredia and isidia; *medulla* white; *lower surface* pale tan, primary rhizines moderate, scattered, black or blackening, but with a thick mass of fine, pale tan, densely branched or agglutinated secondary rhizines developing from the primary rhizines or directly from the lower surface. *Apothecia* common, adnate, to 2mm in diameter, disc more or less flat or shallowly concave, pale brown to cinnamon-brown ; the exciple ecoronate, margin dentate: asci 8-spored, spores simple, colourless, ellipsoid, 5-7 x 4-5 µm.

Chemistry. Thallus K-, medulla K-, C-, KC+ yellow, P- ; containing usnic acid, barbatic acid (major), 4-O-demethylbarbatic acid (minor), obtusatic acid (trace), norobtusatic acid (trace), protocetraric acid (trace).

Morphologically this new species closely resembles *Relicina sublanea* (Kurok.) Hale. Both species are characterised by the pale lower surface with fine, densely branched, pale, agglutinated secondary rhizines arising from the lower surface and primary rhizines, the separate, linear-elongate lobes and the ecoronate apothecia. However these two species are distinguished readily by their medullary chemistry, with *R. sublanea* reacting P+ orange-red due to the presence of protocetraric acid, whereas *R. agglutinata* gives a P- reaction (barbatic acid and 4-O-demethylbarbatic acid). Although these two species are sympatric in Papua New Guinea, *R. sublanea* has a more extensive and more northerly distribution, being known from Indonesia, Malaysia and the Philippines (Hale 1975). The only other *Relicina* with comparable chemistry, *R. incongrua* Hale, is distinguished readily by the jet black, sparsely rhizinate lower surface and the coproduction of diffractaic acid.

Specimens Examined:

Papua New Guinea. Morobe Province. On large *Castanopsis* in *Castanopsis* forest on south-west facing slope, Nauti Logging Area, Upper Watut River, 10km south-west of Bulolo, 7°16'S, 146°36'E, 1400m, *H.Streimann* 17063, 3.iii.1982 (CBG8201190, LAE).

Relicina conglutinata Elix & Johnston, sp. nov. Fig.2

Species thallo ut in *Relicina circumnodata* simili sed ab hac specie acido succinprotocetrarico et acido fumarprotocetrarico continens differt.

Type. Australia. Queensland. On mangroves in tidal flats, 17°01'S, 145°46'E, 1m, *J.A.Elix* 17616 & *H.Streimann*, 8.vii.1984 ; CBG-holotype.

Thallus foliose, corticolous, closely adnate on bark, yellow-green, to 5cm in diameter; *lobes* sublinear-elongate, 0.8-1.5mm wide, separate, sparingly imbricate, dichotomously divided, the margins bulbate ciliate, *cilia* moderate to sparse, commonly vestigial and subglobose to globose, black, then black and inflated at the base but paler towards the apices, up to 0.3mm long. *Upper surface* plane to convex, continuous, shiny at the apices but dull on the older lobes, weakly maculate, moderately to densely isidiate, *isidia* subcylindrical, short, irregularly inflated, simple or rarely sparingly branched; *medulla* white; *lower surface* pale tan, primary rhizines moderate to dense, mottled black and pale tan, with slender secondary rhizines developing from the primary rhizines or directly from the lower surface, secondary rhizines densely branched and becoming conglutinated, secondary rhizines pale, concolorous with the lower surface. *Apothecia* not seen.

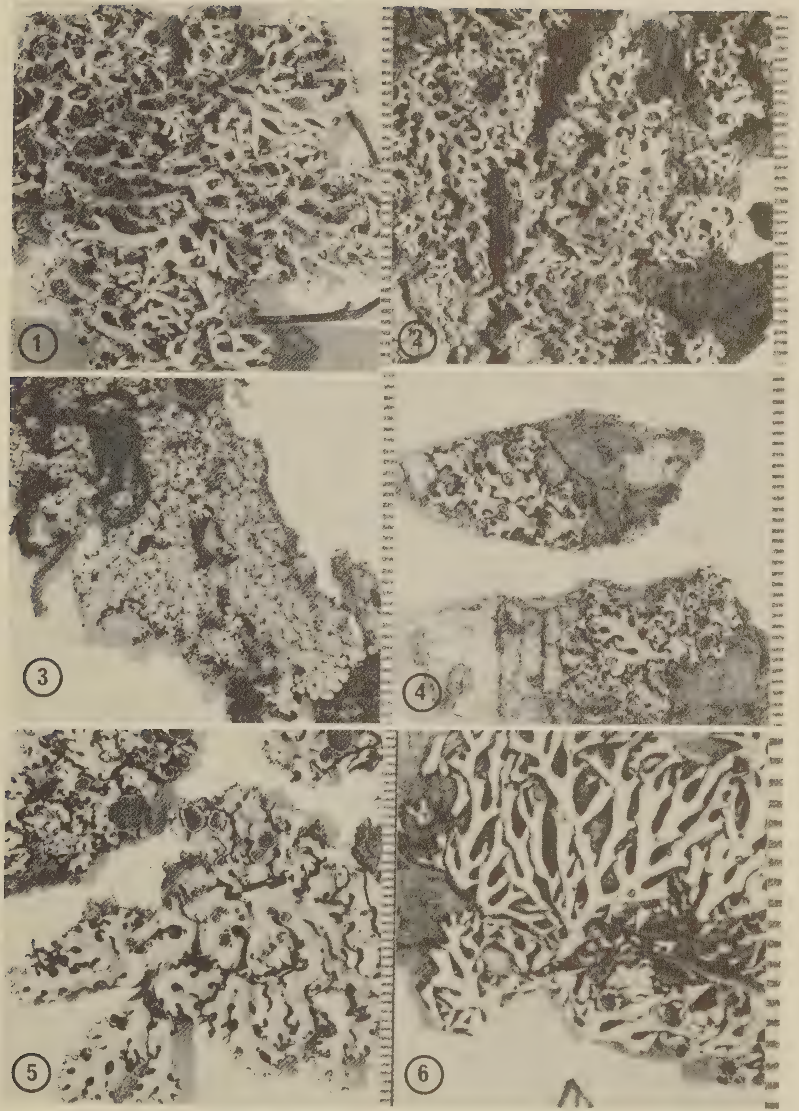
Chemistry. Thallus K-, medulla K-, C-, KC-, P+ brick red; containing usnic acid, succinprotocetraric acid (major), fumarprotocetraric acid (minor), protocetraric acid (trace).

This new species closely resembles the common species, *Relicina circumnodata* (Nyl.) Hale as they have comparable thalli and lobe configurations, produce cylindrical isidia on the upper surface and have pale conglutinated secondary rhizines below. In general the cilia of *R. conglutinata* are more sparse and poorly developed than those of *R. circumnodata* with many vestigial bulbae not developing into true cilia, but these two species are distinguished most readily chemically. Thus the major medullary substance in *R. circumnodata* is protocetraric acid, while *R. conglutinata* produces succinprotocetraric acid and fumarprotocetraric acid. *R. conglutinata* appears to be the isidiate counterpart of *Relicina ramosissima* (Kurok.) Hale. At present *R. conglutinata* is known only from the type locality.

Relicina demethylbarbatica Elix & Johnston, sp. nov. Fig.3

Species thallo ut in *Relicina abstrusa* simili sed ab hac specie acido 4-O-demethylbarbatico (maximo) et acido barbatico (minimo) continens differt.

Type. Australia. Queensland. On felled trees along the rainforest margin, Flaggy Creek,



Figures 1-6. New species of *Relicina*: 1, *R.agglutinata* (holotype in CBG); 2, *R.conglutinata* (holotype in CBG); 3, *R.demethylbarbatica* (holotype in CBG); 4, *R.fijiensis* (holotype in CBG); 5, *R.filsonii* (holotype in MEL); *R.niuginiensis* (holotype in CBG). Scale in mm.

Black Mountain Road, 9km west of Kuranda, 16°47'S. 145°36'E, 420m, *J.A.Elix* 17663 & *H.Streimann*, 7.vii.1984 ; CBG-holotype.

Thallus foliose, corticolous, closely adnate on bark, yellow-green, to 8cm in diameter; *lobes* short, sublinear-elongate, 0.3-1.5mm wide, crowded but sparingly imbricate, the margins bulbate-ciliate; *cilia* numerous, moderately inflated, up to 0.3mm long. *Upper surface* plane, continuous, shiny, emaculate, moderately to densely isidiate; *isidia* cylindrical, short, simple or rarely sparingly branched; *medulla* white; *lower surface* jet black, densely rhizinate, rhizines black, simple. *Apothecia* not seen.

Chemistry. Thallus K-, medulla K-, C-, KC+ yellow, P-; containing usnic acid, 4-O-demethylbarbatic acid (major), barbatic acid (minor).

This new species closely resembles the common species, *Relicina abstrusa* (Vainio) Hale as they have comparable thalli and lobe configurations and both have simple, cylindrical isidia on the upper surface. Generally thalli of *R. demethylbarbatica* are more diminutive, but these two species are distinguished most reliably chemically. Thus the major medullary substance in *R. abstrusa* is norstictic acid which gives K+ yellow turning red, C-, P+ orange medullary reactions, while the medulla of *R. demethylbarbatica* reacts K-, C-, P-, KC+ yellow due to the presence of 4-O-demethylbarbatic acid. The unique chemistry distinguishes this new species from ali known *Relicina* .

Specimens Examined:

Australia. Queensland. In "dry" rainforest on *Acacia* , slopes of Black Mountain, 25km north-west of Kuranda, 16°40'S, 145°29'E, 500m, *J.A.Elix* 17492 & *H.Streimann*, 7.vii.1984 (ANUC); on bark, logging area in rainforest, end of Clohesy River Road, *ca*.. 16km south-east of Kennedy Hwy., west of Cairns, 800m, *M.E.Hale,* s.n., 8.viii.1983 (US); on bark, logging area in rainforest, near end of Black Mountain Road, 33km west-north-west of Kuranda, 800m, *M.E.Hale* 64085, 20.viii.1983 (US).

Relicina fijiensis Elix & Johnston, sp. nov. Fig.4

Species thallo ut in *Relicina samoensis* simili sed ab hac specie acido incognito continens differt.

Type. Fiji. Viti Levu. On trees along the roadside in regrowth forest, Nasori Highlands, Nadi-Sigatoka Road, 3.6km west of Vanturu Dam turnoff, *J.A.Elix* 15116, 26.viii.1983 ; CBG-holotype.

Thallus foliose, corticolous, closely adnate on bark, yellow-green, to 5cm in diameter; *lobes* short, sublinear, 0.3-1.0mm wide, crowded but sparingly imbricate, the margins bulbate-ciliate; *cilia* conspicuous, bulbae globose, cilia up to 1.0mm long, rarely branched. *Upper surface* plane, slightly shiny, emaculate, lacking soredia and isidia; *medulla* white; *lower surface* jet black, sparsely rhizinate, rhizines black, simple or sparingly branched. *Apothecia* common, adnate, to 1.5mm in diameter, disc more or less flat, pale brown to brown; the exciple coronate, amphithecium retrosely rhizinate; asci 8-spored, spores simple, colourless, broad-ellipsoid, 5.5-7 x 3.5-4.5mm.

Chemistry. Thallus K-, medulla K+ pale yellow, C-, KC-, P-; containing usnic acid and hirtifructic acid [R_F in solvents A/B/C (Culberson 1972): 50, 31, 38; solvent B' (Culberson & Johnson 1982): 35; develops as a pale orange spot after spraying with sulfuric acid and heating].

This new species would appear to be closely related to *Relicina samoensis* (Zahlbr.) Hale as they have comparable thalli, coronate apothecia, a black lower surface and lack isidia. However the thalli of *R. fijiensis* are compact, with more or less contiguous lobes, dense cilia and retrose apothecial rhizines, whereas *R. samoensis* has separate lobes with moderately dense cilia and retrose rhizines. Even so these two species are distinguished most reliably chemically. Thus the major medullary substance in *R. samoensis* is echinocarpic acid while *R. fijiensis* produces hirtifructic acid. The latter substance was first recognized in *Relicina hirtifructa* (Kurok.) Streim. although the structure of this compound remains unknown. This new species differs morphologically from *R. hirtifructa* since the latter species has much more robust thalli, broader lobes (1.5-3.0mm) and ecoronate apothecia.

Specimen Examined:

Fiji. Viti Levu. On tree in regrowth forest, Nasori Highlands, Nadi-Sigatoka Road, 13km east of the Vanturu Dam turnoff, *J.A.Elix* 15224, 27.viii.1983 (ANUC).

Relicina filsonii Elix & Johnston, sp. nov. Fig.5

Species thallo ut in *Relicina limbata* simili sed ab hac specie acido norstictico (maximo), acido connorstictico (minimo) et acido hyposalazinico (vestigio) continens differt.

Type. Australia. New South Wales. On tree, Kerripit River, Gloucester Tops, *R.Filson* 11174, 15.i.1969 ; MEL 1028512-holotype.

Thallus foliose, corticolous, adnate on bark, yellow-green to yellow-brown on storage, to 5cm in diameter; *lobes* linear-elongate, contiguous centrally to separate at the periphery, 1.5-3.0mm wide, not imbricate, subdichotomously divided, the margins bulbate-ciliate; *cilia* dense and conspicuous, black, to 2.0mm long. *Upper surface* plane to weakly convex, continuous, shiny at the apices, weakly maculate, lacking soredia and isidia; *medulla* white; *lower surface* brown to dark brown, rhizines dense, brown to black, simple or occasionally dichotomously branched. *Apothecia* common, adnate, to 3mm in diameter, disc more or less flat or shallowly concave, cinnamon-brown; the exciple ecoronate, amphithecium retrorsely rhizinate: asci 8-spored, spores simple, colourless, ellipsoid, 7-9 x 4-6 µm.

Chemistry. Thallus K-, medulla K+ yellow-red, C-, KC-, P+ orange; containing usnic acid, norstictic acid (major), connorstictic acid (minor), hyposalazinic acid (trace).

Morphologically this new species closely resembles *Relicina limbata* (Laurer) Hale. Both species are characterised by the brown lower surface with broad, linear-elongate lobes which lack isidia, and the ecoronate apothecia. However these two species are distinguished readily by their medullary chemistry: *R. limbata* reacts K+ yellow due to the predominance of stictic acid (with minor quantities of norstictic, constictic and cryptostictic acids), whereas *R. filsonii* gives a K+ yellow then red reaction due to the predominance of norstictic acid (with minor quantities of connorstictic and hyposalazinic acids). Although these two species are sympatric in New South Wales, *R.limbata* has a more extensive distribution, being known from Tasmania to north Queensland. At present this new species is known only from the type locality. The only other *Relicina* with comparable chemistry and morphology, *R.subabstrusa* Hale, is distinguished by the jet black lower surface.

Relicina niuginiensis Elix & Johnston, sp. nov. Fig.6

Species thallo ut in *Relicina relicinula* simili sed ab hac specie thallo elobulato et acido gyrophorico et acido incognito continens differt.

Type. Papua New Guinea. Morobe Province. On upper branches of large tree on *Castanopsis* and Dipterocarpaceae-dominated ridge, Herzog Mountains, 15km west-south-west of Lae, 6°45'S, 146°51'E, 760m, *H.Streimann* 10932, 13.i.1981 ; CBG-holotype

Thallus foliose, corticolous, closely adnate on bark, yellow-green, to 3cm in diameter; *lobes* sublinear-elongate, 0.3-1.0mm wide, separate, not imbricate, dichotomously divided, the margins bulbate-ciliate; *cilia* very dense and conspicuous, up to 1.0mm long, simple or often branched. *Upper surface* plane, shiny, emaculate, lacking soredia and isidia; *medulla* white; *lower surface* jet black, sparsely rhizinate, rhizines black, simple or sparingly branched. *Apothecia* common, adnate, to 1.5mm in diameter, disc more or less flat, pale brown to brown; the exciple coronate, amphithecium retrorsely rhizinate; asci 8-spored, spores simple, colourless, broad-ellipsoid, 5-5.5 x 3.5-4.5mm.

Chemistry. Thallus K-, medulla K-, C-, KC-, P+ yellow; containing usnic acid, gyrophoric acid (trace), hirtifructic acid (major), unknown (trace).

This new species would appear to be closely related to *Relicina relicinula* (Müll.Arg.) Hale since both species have narrow, sublinear-elongate, dichotomously divided lobes which are well separated at the periphery. These two species can, however, be distinguished both morphologically and chemically. *R. relicinula* typically is lobulate with continuous, crowded central lobes and contains only usnic acid and pale unknowns while *R. niuginiensis* is elobulate with well separated lobes throughout and contains usnic acid, gyrophoric acid and hirtifructic acid. This species also could be confused with *R. fijiensis* since they are similar morphologically and chemically. However the lobes of *R. fijiensis* are shorter, more compact and crowded and this species contains only hirtifructic acid and usnic acid. *R. niuginiensis* is distinguished by the more elongated, well separated lobes and the presence of additional gyrophoric acid and an unknown substance (which appears to be related to the compounds present in *Relicina butleri* (Elix) Elix & Johnston).

Specimen Examined:

Papua New Guinea. Morobe Province. On *Pometia* trunk, in *Endospermum medullosum* and *Pometia pinnata* dominated forest on slope, Buso River, 26km east-north-east of Lae, 6°43'S, 147°14'E, 160m, *H.Streimann* 11621 & *T.Umba*, 16.i.1981 (CBG 8105180).

New Combination

Relicina butleri (Elix) Elix & Johnston comb.nov.
Basionym: *Parmelia butleri* Elix, Aust.J.Bot., **27**, 876 (1979).

ACKNOWLEDGEMENTS

We thank the Australian National University for generous financial support of this project through the Faculties Research Fund. We thank Dr.M.E.Hale for his cooperation, advice and assistance in obtaining critical type material. We also wish to thank Mr.I.A.Fox and the staff of the Science Photographic Unit, ANU, for preparing the photographs, Mr.D.Verdon for checking the Latin descriptions and Dr. G.A.Jenkins who determined the chemistry of many specimens. We thank the following colleagues for making collections available: Mr.R.Filson (MEL), Dr.M.E.Hale (US), Mr.P.Lambley (UPNG), Mr.H.Streimann (CBG), Dr.S.Kurokawa (TNS).

LITERATURE CITED

Culberson, C.F. (1972). Improved conditions and new data for the identification of lichen products by a standardized thin-layer chromatographic method. *J. Chromatogr.*, **72**, 113-125.

Culberson, C.F. and Johnson, A. (1982). Substitution of methyl *tert.*-butyl ether for diethyl ether in the standardized thin-layer chromatographic method for lichen products. *J. Chromatogr.*, **238**, 483-487.

Elix, J.A. and Stevens, G.N. (1979). New species of *Parmelia* (lichens) from Australia. *Aust. J. Bot.*, **27**, 873-883.

Hale, M.E.Jr. (1973). Fine structure of the cortex in the lichen family Parmeliaceae viewed with a scanning electron microscope. *Smithsonian Contrib. Bot.,* **10**, 1-92.

Hale, M.E.Jr. (1974). *Bulbothrix, Parmelina, Relicina*, and *Xanthoparmelia*, four new genera in the Parmeliaceae (Lichenes). *Phytologia*, **28**, 334-339.

Hale, M.E.Jr. (1975). A monograph of the lichen genus *Relicina* (Parmeliaceae). *Smithsonian Contrib. Bot.*, **26**, 1-32.

Kashiwadani, H. (1975). Enumeration of *Anaptychiae* and *Parmeliae* of Papua New Guinea. In Otani, Y. : Reports on the cryptogams in Papua New Guinea (Natn.Sc.Mus., Tokyo), 75-85.

Kurokawa, S. (1979). Enumeration of species of *Parmelia* in Papua New Guinea. In Kurokawa, S. : Studies on cryptogams of Papua New Guinea (Academia Scientific Book Inc., Tokyo), 125-150.

Lumbsch, H.T. and Elix, J.A. (1985). A new species of the lichen genus *Diploschistes* from Australia. *Pl. Syst. Evol.*, **150**, 275-279.

Stevens, G.N. (1981). The macrolichen flora on mangroves of Hinchinbrook Island, Queensland. *Proc. R. Soc. Qd.*, **92**, 75-84.

AUTHOR INDEX, VOLUME TWENTY-SEVEN

ABDULLAH, SAMIR K., *see* UDAGAWA & AL.

AGERER, R., Studies on ectomycorrhizae III. Mycorrhizae formed by four fungi in the genera *Lactarius* and *Russula* on spruce 1-59

ANON., Notice: Guide to Sanctioned Fungal Names 404

AWAO, TAKEYOSHI, *see* UDAGAWA & AL.

BAGYANARAYANA, G., & U. BRAUN, A new species of the genus *Oidium* from India 61-62

BEN-ZE'EV, ISRAEL S., Notes on Entomophthorales (Zygomycotina) collected by T. Petch: II. *Erynia ellisiana* sp. nov., non *Erynia forficulae* (Giard), comb. nov., pathogens of Forficulidae (Dermaptera) 263-269

BONDE, M. R., *see* MICALES & AL.

BORSE, B. D., *see* HYDE & BORSE

BRAUN, U., *see* BAGYANARAYANA & BRAUN

BRODO, IRWIN M., A new species of the lichen genus *Sulcaria* (Ascomycotina, Alectoriaceae) from California 113-117

BRUSSE, FRANKLIN A., Five new species of *Parmelia* (Lichenes, Parmeliaceae) from southern Africa 183-192

BRUSSE, FRANKLIN A., Four new effigurate-crustose species of *Parmelia* (Lichenes, Parmeliaceae) from southern Africa 237-245

BURDSALL, HAROLD H., JR., *Platygloea acanthophysa,* a new species with single sterigmate basidia and acanthophyses 499-502

CANDOUSSAU, FRANÇOISE, Récoltes de *Biscogniauxia dennisii* (Pyrenomycetes, Ascomycetes) dans le sud-ouest de la France 555-562

COURTECUISSE, RÉGIS, Notes de nomenclature concernant les Hyménomycètes; IV. Sur quelques épithètes spécifiques préoccupés. 3. 127-145

ELIX, JOHN A., & JEN JOHNSTON, New species of *Relicinia* (lichenized Ascomycotina) from Australasia 611-616

ELIX, JOHN A., JEN JOHNSTON, & DOUGLAS VERDON, *Canoparmelia, Paraparmelia* and *Relicinopsis*. Three new genera in the Parmeliaceae (lichenized Ascomycotina) 271-282

ERIKSSON, OVE, *Lahmia* Körber (= *Parkerella* A. Funk) a misinterpreted genus with isolated position 347-360

ERIKSSON, OVE, *see* YUE & ERIKSSON

ERIKSSON, OVE, & JING-ZHU YUE, *Bertiella* (Sacc.) Sacc. & Sydow a synonym of *Massarina* Sacc. 247-253

FRANK, HARALD M., Macrochemical color reactions of macromycetes II. Chemical properties and systematic position of *Bondarzewia mesenterica* 503-506

FUNK, A., Two new discomycetes on *Pinus* 283-288

GJÆRUM, HALVOR B., East African rusts (Uredinales), mainly from Uganda 5. On families belonging to Gamopetalae 507-550

HALE, MASON E., JR., New species of the lichen genus *Xanthoparmelia* from southern Africa (Ascomycotina: Parmeliaceae) 563-610

HALLENBERG, NILS, Cultural studies in *Tubulicrinis* and *Xenasmatella* (Corticiaceae, Basidiomycetes) 361-375

HANLIN, R. T., & R. A. SAUNDERS, Confirmation of *Ascosphaera apis* in Georgia 551-554

HO, H. H., & S. C. JONG, A comparison between *Phytophthora cryptogea* and *P. drechsleri* 289-319

HUMBER, RICHARD A., *see* ROMBACH & AL.

HYDE, K. D., & B. D. BORSE, Marine fungi from Seychelles. VI. *Massarina velataspora,* a new marine Ascomycotina from mangrove wood 161-167

JOHNSTON, JEN, *see* ELIX & JOHNSTON

JOHNSTON, JEN, *see* ELIX & AL.

JONES, E. B. GARETH, *Digitatispora lignicola,* a new marine lignicolous Basidiomycotina 155-159

Jong, S. C., *see* Ho & Jong

Koske, R. E., & Christopher Walker, Species of *Scutellospora* (Endogonaceae) with smooth-walled spores from maritime sand dunes: two new species and a redescription of the spores of*Scutellospora pellucida* and *Scutellospora calospora* 219-235

Kunwar, I. K., J. B. Manandhar, & J. B. Sinclair, *Badarisama sojae,* a new bulbil-forming genus and species 119-125

Lindsey, J. Page, Basidiomycetes that decay Gambel oak in southwestern Colorado: III. 325-345.

Manandhar, J. B., *see* Kunwar & al.

Micales, J. A., M. R. Bonde, & G. L. Peterson, The use of isozyme analysis in fungal taxonomy and genetics 405-449

Miller, Steven L., Hypogeous fungi from the southeastern United States I. The genus *Rhizopogon* 193-218

Nagarkar, M. B., P. K. Sethy, & P. G. Patwardhan, Materials for a lichen flora of the Andaman Inslands — I 71-82

Onofri, Silvano, *see* Zucconi & Onofri

Patwardhan, P. G., *see* Nagarkar & al.

Peterson, G. L., *see* Micales & al.

Perini, Claudia, A new *Chlamydomyces* species from Italy 255-261

Reynolds, Don R., Foliicolous ascomycetes 7. Phylogenetic systematics of the Capnodiaceae 377-403

Roberts, Donald W., *see* Rombach & al.

Rombach, Michiel C., Richard A. Humber, & Donald W. Roberts, *Metarhizium flavoviride* var. *minus,* var. nov., a pathogen of plant- and leafhoppers on rice in the Philippines and Solomon Islands 87-92

Ryvarden, L., *Tremellostereum* (Tremellaceae) nov. gen. 321-323

Sanders, F. E., *see* Walker & Sanders

Saunders, R. A., *see* Hanlin & Saunders

Schipper, M. A. A., *Hyphomucor,* a new genus in the Mucorales for *Mucor assamensis* 83-86

Sethy, P. K., *see* Nagarkar & al.

Simmons, Emory G., *Gibbago,* a new phaeodictyoconidial genus of hyphomycetes 107-111

Sinclair, J. B., *see* Kunwar & al.

Tsubouchi, Haruo, *see* Udagawa & Tsubouchi

Udagawa, Shun-ichi, & Haruo Tsubouchi, *Coniochaetidium mirabile,* a new ascomycete isolated from salted food 63-69

Udagawa, Shun-ichi, Takeyoshi Awao, & Samir K. Abdullah, *Thermophymatospora,* a new thermotolerant genus of basidiomycetous hyphomycetes 99-106

Verdon, Douglas, *see* Elix & al.

Walker, Christopher, *see* Koske & Walker

Walker, Christopher, & F. E. Sanders, Taxonomic concepts in the Endogonaceae: III. The separation of *Scutellospora* gen. nov. from *Gigaspora* Gerd. & Trappe 169-182

Weber, William A., The lichen flora of the Galápagos Islands, Ecuador 451-497

Yue, Jing-zhu, *see* Eriksson & Yue

Yue, Jing-zhu, & Ove Eriksson, Studies on Chinese ascomycetes. 3. *Astrosphaeriella lageniformis* 93-98

Zucconi, Laura, & Silvano Onofri, Two new dematiaceous hyphomycetes from tropical forest litter 147-153

INDEX TO FUNGOUS AND LICHEN TAXA, VOLUME TWENTY-SEVEN

This index includes the names of genera, infrageneric taxa, species, and infraspecific taxa. New names are *italicized*, as are the page numbers on which such new taxa are proposed. New names of suprageneric taxa appear in *italic CAPITALS*.

Absidia 84
Acarospora chlorophana 458; schleicheri 459
Acaulospora 229, 231
Acremoniella atra 259
Acrogenotheca 378, 381, 384, 386, 388, 398, 399; elegans 382
Actinomucor 84
Aecidium 511; acanthacearum 535; *aspiliae* 507, *508*, 544; barleriae 527; celosiae 544; cephalandrae 520; clerodendri 514; conyzae-pinnatilobatae 512; cookeanum 546; crassocephali 510, 511; cynanchi 508, 545; dichrocephalae 509, 545; dissotides 536; dubiosum 509, 547; *echuyaënse* 507, *509*, 510, 545; emiliae 510, 511; englerianum 544; flavidum 510, 546; fluggeae 547; formosanum 510, 511; gynurae 510, 511, 545; gynurae-cernuae 510, 511; *haplocarphae* 507, *511*, 512, 545; hartwegiae 544; helichrysi 509; hoffmannii 512; justicia 533; macowanianum 512, 545; mariani-raciborskii 511; metapense 509; mitracarpi 520; ocimi 531, 546; ornithogaleum 546; plectranthi 512, 513, 547; plectranthicola 513; popowiae 546; pycnostachydis 513, 547; ranunculacearum 547; torae 544; verononiae-podocomae 513, 548
Agaricus 407, 505; bisporus 409; brunnescens 436; campestris 436; cyaneus 138, 139; incanus v polychrous 132; undulatellus 142; virescens 128-131
Aigialus grandis 161; parvus 161
Alectoria 113, 114, 276; imshaugii 114; sarmentosa 481, 488
Aleurodiscus cerrusatus 344
Allantoparmelia 274
Alpova 202; subg Antridium 202; klikae 202
Alternaria 107, 110, 111, 120; alternata 119, 120, 122; helianthi 110; leucanthemi 110
Amphinema byssoides 342
Anaptychia circinalis 470; comosa 470; corallophora 470; leucomelaena 488; podocarpa 470, 488; stellata 470; f verrucifera 470; tropica v antillarum 470
Angiopsora wiehei 517, 523
Aniptodera mangrovii 161
Antennulariella 378, 381, 384, 386, 388, 390, 393, 394, 398, 399
'ANTENNULARIELLOIDEAE' [nom. prov.] *398*
Anthracothecium leucostomum 459; ochraceoflavum 459; pyrenuloides 459
Armillaria mellea 325, 326, 341
Arthonia 488; cinnabarina 460, 488; gregaria 460, 488; nivea 488; platyspilea 459, 460; tumidula 460
Arthrothelium galapagoense 459-461; spilomatoides 460
Arthrorhaphis grisea 356
Ascidium massalongoi 80; xanthostromiza 78
Ascosphaera apis 551-553
Aspergillus 255-260
Aspidophyllum fugiens 460, 469, 486
Astrosphaeriella 93, 97; aosimensis 97; *lageniformis* 93, *94*, 97, 98
Athelia bombycina 343; coprophila 343

Bacidia 459; apiahica 460; insularis 459, 460; luteola 460; millegrana 460; rubella 460; subleporina 461
Badarisama 119, *120*, 123, 124; *sojae* 119-*121*, 122, 124
Bertia subg Bertiella 249; macrospora 248-251; moriformis v latispora 247; parasitica 249
Bertiella 247, 249, 250; macrospora 247, 253; polyspora 250
Biatriospora marina 161
Biscogniauxia 555, 557; dennisii 555-561; marginata 557; repanda 557
Bondarzewia 503; mesenterica 503, 505; montana 503
Borrera leucomelos 454
Botryobasidium botryosum 343
Bremia lactucae 437
Brigantiaea leucoxantha 461
Brooksia 398
Bryoria 113, 114, 276; sect Implexae 114; furcellata 114; kuemmerleana 114; smithii 114; spiralifera 114
Buellia 459, 488, 491; canescens 466; dejungens 461; galapagona 459, 461; glaziouana 451, 493; lauricassiae 461; *mamillana* 451, 461, *493;* modesta 461; parasema 461; straminea 459, 461, 462, 488, 490; umbrina 488; xanthinula 488
Bulbothrix 276; laevigatula 462
Burgoa 119, 124; nigra 124; verzuoliana 120, 124
Byssoloma subdiscordans 462, 474, 485; tricholomum 462
Byssoporia terrestris 44, 45, 47, 48; v aurantiaca 47; v sartoryi 47

Calopisma byrsonimae 462
Caloplaca 463; byrsonimae 462; camptidia 462; cirrochroa 462; elegans 463, 488; floridana 463; isidiosa 463, 488, 489; muelleri 463, 488, 491;

[Caloplaca] murorum 489; rugulosa 463, 489
Calosphaeria 355
Canoparmelia 271-277; *adspersa* 278; *amazonica* 278; *aptata* 278; *caribaea* 274, 278; *carneopruinata* 274, 278; *caroliniana* 274, 278; *cinerascens* 278; *concrescens* 278; *corrugativa* 278; *crozalsiana* 274, 278; *cryptochlorophaea* 278; *ecaperata* 276, 278; *epileuca* 278; *eruptens* 278; *inhaminensis* 278; *inornata* 278; *martinicana* 278; *nairobiensis* 278; *norsticticata* 278; *raunkiaeri* 278; *salicinifera* 274, 279; *schelpei* 279; *scrobicularis* 279; *somaliensis* 279; *subtiliacea* 279; *texana* 274, 277, 279; *zambiensis* 276, 279; *zimbabwensis* 279
Capnodium 378, 381, 382, 386, 388, 394, 397, 399; walteri 380, 384
Caryosporella rhizophorae 161
Ceraceomyces serpens 325, 327, 343
Ceratobasidium cornigerum 326, 327, 343
Ceratocladium 149
Ceriporia excelsa 341; reticulata 341; tarda 341
Ceriporiopsis mucida 341
Chiodecton effusum 463; farinaceum 463; myrticola 463; sanguineum 469, 489
Chlamydomyces 255, 259, 260; diffusus 259; palmarum 259, 260; *sympodialis 255*, 257, 258, 260
Chrysosporium 103
Chrysothrix candelaris 463, 466
Circinotrichum 147, 149; britannicum 149; fertile 149, 150; *flagelliforme 147*-149; papakurae 149; rigidum 149, 150
Cladia 453; aggregata 463
Cladina 453, 464; confusa 463, 489; sandstedei 464
Cladobotryum 63, 67
Cladonia 463, 494; balfourii 464, 489; cariosa 465; ceratophylla 464; chlorophaea 464, 489; didyma 464; fimbriata 489; furcata f adspersa 489; galapagosensis 463, 464, 489; macilenta ssp theiophila 464; pityrea 465, 489; polia 463, 464, 489; pycnoclada 489; sphacelata 465; subcariosa 465; subsquamosa 465; subulata 465; symphoriza 465
Claudopus 140; subg Claudopus 140; subg Paraleptonia 140; cyaneus 140; cyanomelaenus 140
Claussenomyces 287, 288; dacrymycetoideus 287; olivaceus 287; *pini 283*, 284, 287; prasinulus 287; pseudotsugae 287
Clavaria 323
Clitopilus flavidus 140, 141
Coccocarpia erythroxyli 466; palmicola 465, 466, 490; pellita v parmelioides 466
Coccoidea 355
Coccotrema granulatum 490
Coenogonium 489
Coleosporium 538; clematidis 544; mitteri 538
Collema furfuraceum 466
Colletotrichum 437
Conidiobolus 264
Coniochaetidium 63, 67; *mirabile 63*, 65-68; ostreum 63, 66, 67
Coprinus cinereus 103, 409; delicatulus 103
Cora pavonia 466, 489
Cortinarius subg Leprocybe 49; hochstetteri 132
Corynella 287
Cronartium coleosporioides 284
Crumenulopsis 288; *lacrimiformia* 283, 284, *286*, 287; pinicola 288
Cryphonectria 436

Dacrymyces minor 340
Dendrostilbella 283
Dictyonema guadelupense 466, 489; montanum 466, 489; sericeum 466, 489
Didymella 250
Dietelia impatientis 546
Digitatispora *lignicola 155*, 157, 158; marina 155, 157, 158
Dimerella lutea 466
Diploicea canescens 463, 466
Diploschistes actinostomus 466, 489; bryophilus 467; muscorum 467; scruposus 467, 490
Dirina approximata 467, 489; herrei 467, 489
Dirinaria 489-491; aegialita 467, 491; applanata 467, 468, 491; caesiopicta 467, 491; confluens 467; leopoldii 468, 491
Disporotrichum dimorphosporum 105

Eccilia 144; subg Nolanea 141; subg Omphalopsis 144; sect Endochromonema 141; subsect Cheilocystidiata 141; subsect Icterina 141; flavida 141, 142; mexicana 142; tenuipes 143, 144
Echinoplaca 462
Embellisia 107, 111
Empusa forficulae 263; v major 263, 264, 266-268
Endocarpon pusillum 468
Endogone 171; calospora 180; heterogama 180
Endophyllum 514; macowanii 514; striatosporum 514, 547; superficiale 514, 544
Endothia gyrosa 436; parasitica 436
Entoloma 127, 128, 132, 140, 143, 144; subg Leptonia 133, 139; subg Paludocybe 133; sect Albidicaules 133; sect Leptonia 139; sect Paludocybe 133; sect Staurospori 133; aeruginosum 128-132; albidum 132, 133; allochroum 139; canum 132; cinerascens 132; convexum 133, 134; cyaneum 138-140; dichroum 139; *egonii* 127, *133;* flavidum 140, 141; *flavoides* 127, *141*, 142; gracile 133; *guzmanii* 127, *143;* hebes 144; hesleri 133, 134; hochstetteri 132; *largentii* 127, *134*, 135, 138; v *alnicola* 127, *136*, 137; v *badiodorsum* 127, *135*, 136; v *farinaceum* 127, 137, *138;* leptopus 144; mexicanum 142, 143; omphaliaeformis 144; porphyrophaeum 138; *subaeruginosum* 127, *128;* subcaeruleum 142; tenuipes 144; tjallingiorum 139; velatum 139; violaceum 138; *virescens* 127, 129, *131*
Entomophthora 264, 407; forficulae 263, 264, 266-268
Erioderma pusillum 468
Erynia 263, 266, 268; subg Furia 268; subg Zoophthora 269; *ellisiana* 263, 264, *266*-268; *forficulae* 263, *268*, 269; suturalis 266

Euantennaria 378, 381, 382, 386, 388, 390, 391, 393, 394, 396, 398, 399
Everniastrum vexans 468, 490
Exidia glandulosa 339, 340

Fibulomyces mutabilis 343
Flavoparmelia 272-276
Flavopunctelia 272, 274
Fomitopsis pinicola 370
Fracchiaea heterogena 250
Fusarium solani 409

Gibbago 107, 108, 111; *trianthemae 107*, 108, 110, 111
Gigaspora 169-172, 174, 177-179, 226; albida 179; alborosea 180; aurigloba 180; calospora 171, 174, 175, 177, 179, 180; candida 179; coralloidea 181; decipiens 179; dipapillosa 181; erythropa 181; gigantea 171, 177, 179; gilmorei 181; gregaria 181; heterogama 170, 171, 175, 177, 178, 180; margarita 170-172, 178, 179; minuta 180; nigra 174, 175, 181; pellucida 181; persica 181; reticulata 169, 181; rosea 179, 226; savannicola 180; tricalypta 180; verrucosa 181
Gloeophyllum sepiarium 326, 328, 342; trabeum 328, 342
Gloeoporus dichrous 321
Glyphus 469; afzelii 469; caesiella 469; cicatricosa 468; desquamescens 469; striatula 469; subamylacea 469
Graphina virginea 468
Graphium 67
Gyalectidium filicinum 469
Gymnoderma 494
Gymnopilus sapineus 341
Gyrothrix 149; pediculata 149

Haematomma puniceum 469
Halocyphina villosa 158
Halosarpheia abonnis 161; ratnagiriensis 161
Hamaspora engleriana 547; longissima 547
Hapalopilus nidulans 341
Hemileia canthii 514, 515, 544; holstii 515, 547; scholzii 515, 544; vastatrix 515, 545; woodii 516, 547
Herpothallon sanguineum 469, 489
Heterodermia albicans 469; antillarum 469, 470; comosa 470, 488; corallophora 470; lepidota 470; leucomela 454, 470, 471, 488, 491; lutescens 471
Hygrophorus cyaneus 132; hochstetteri 132
Hymenochaete arida 344
Hyphoderma *anasaziense* 325, *328*, 329, 344; medioburiense 329, 330, 345; praetermissum 345
Hyphodontia 364, 365, 374; arguta 342; crustosa 339, 342; subalutacea 342
Hyphomucor 83, 84; *assamensis* 83, *84*-86
Hypogymnia mollis 113
Hypotrachyna costaricensis 471; microblasta 471
Hypoxylon 557

Idriella 150; fertilis 150

Incrustoporia nivea 341
Inonotus andersonii 339, 342; dryophilus 341
Itersonilia perplexans 499, 501

Kavinia himantia 331, 342
Kirschsteinia polyspora 250

Lactarius 1, 14, 46, 47, 503; deliciosus 10, 12, 14; v picinus 10; deterrimus 1, 2, 4, 6, 8, 10, 12, 14, 21, 46, 50, 51; griseus 50; maculatus 50; obscuratus 49; picinus 1, 2, 8, 10, 15, 16, 18, 20, 21, 23, 46, 50; rufus 45, 46, 51, 53; salmonicolor 14; sanguifluus 10, 14, 51
Laeticorticium simplicibasidium 499, 501
Lahmia 347, 348, 352-357; fueistingii 356; kunzei 347-353, 355-358; picea 356
LAHMIACEAE 357
LAHMIALES 357
Lahmiomyces 356
Lecanora 490; atra 485; caesiorubella 114; ssp glaucomodes 471; floridana 463; glaucovirens 489; leprosa 471, 472; leptoplaca 242; pseudopinguis 459, 461, 471; punicea 469; sulfurescens 471
Lecidea 472; aeruginosa 472; chilena 472; coarctata 485; glaziouana 493; granifera 471, 472, 490; granulosa 485-486; oreinoides 472, 488
Lentinellus cochleatus 340
Lentinus edodes 409, 436
Lepolichen coccophorus 490; colobinus 490
Lepraria candelaris 463
Leprocaulon microscopicum 472; tenellum 472
Leptogium cyanescens 472; isidiosellum 472; marginellum 473; milligranum 473; punctulatum 473
Leptonia aeruginosa 128; albida 132, 133; cinerascens 132; convexa 133-135; v alnicola 136; v badiodorsa 134, 135; v farinacea 138; cyanea 138; mexicana 142; subcaerulea 142; undulatella 142
Leptoniella acericola 139; aeruginosa 128; albida 132-134; mexicana 142
Leptosphaeria avicenniae 166; coccodes 251; contecta 166; senegalensis 250
Leptotrema 72, 489; bahianum 74; compunctum 474; elachistoteron 72, 82; mastoideum 490; *nuwarense* 71, *74*, 82; *pertusarioides* 71, *74*, 82; reclusum 72, 74, 82; wightii 474
Limacinia 378, 381, 382, 386, 388, 390, 394, 396-399; fernandeziana 382, 384
'LIMACINIOIDEAE' [nom. prov.] *397*
Limacinula 378, 381, 382, 386, 388, 393, 394, 397, 399; anomala 384
Lobaria dissecta 473
Lopadium foliicola 473, 485; fuscum 473; puiggarii 473
Lophiosphaera 250; beckhausii 252
Lophiostoma 247, 250, 251, 253; angustilabrum 251; arundinis 249, 251; semiliberum 249, 251; subcorticale 249-251
Lophiotrema 250
Lophodermium juniperinum 353

Massarina 161, 165, 166, 247, 250, 251, 253; aquatica 165, 166; *coccodes* 247, *251*, 253; cystophorae 165, 166; eburnea 250; *macrospora* 247, *248*, 250-253; 'sp. 1' 166; 'sp. 2' 166; *velataspora 161*-166
Melampsora euphorbiae 545, 547
Melanaspicilia 493
Melanelia 274
Melanotheca cruenta 473
Metacapnodium 378
Metarhizium 87, 91; album 88, 91; anisopliae 87, 88, 90; v anisopliae 88; v majus 88; flavoviride 87-90, 92; v flavoviride 87, 89-91; v *minus* 87, *89*-92
Metasphaeria 250, 251; sepincola 251
Minimedusa 119, 124
Mortierella 84
Mucor 83, 84; assamensis 83, 84; 'tax. sp. II' 86
Myceliophthora 99, 103
Mycogone 259; cervina 259; rufa 259
Myriotrema compunctum 474; nuwarense 74; olivaceum 76, 474; wightii 474

Neofuscelia 274
Neovossia horrida 437
Neurospora 407
Nia vibrissa 158
Niebla 474; ceruchoides 474
Nimbospora bipolaris 166
Nitschkia broomeiana 250
Nodulisporium 557
Nolanea tenuipes 144
Normandina pulchella 474
Nummularia 557; dennisii 556; discreta 557

Ocellularia 72; allosporoides 75, 82; berkeleyana 75, 78, 82; cavata 79; diacida 75, 82; glaucula 76; glaziovii 78; micropora 76; olivacea 71, 76, 82; pycnophragmia 76, 82; terebrans 76, 82; *wandoorensis* 71, *78*, 82; xanthostromiza 71, 78, 82
Ochrolechia pallescens 474
Oidium 61, 62; abelmoschii 62; candicans 343; *pavoniae 61*, 62; schmiedeknechtii 62; urenae 62
Ophiocapnocoma 378, 394

Pannaria molybdaea 466, 490; pannosa 474
Panus rudis 340
Papulaspora 119; atra 124; pannosa 120, 124; parasiticum 119
Paraparmelia 271-277, *279; adusta 279; alabamensis 279; annexa 279; arcana 279; astricta 279; basutoensis 279; capnoides* 276, *280; cerussata 280; condyloides 280; conranensis 280; fumigata* 276, *280; interposita* 276, *280; ischnoides 280; lecanoracea 280; lithophila 280; lithophiloides 280; molybdiza 280; mongaensis 280; murina 280; nana 280; neoquintaria 280; numinbahensis 280; owariensis 280; prolata 280; pustulescens 280; rodriguesiana 280; rupicola 281; schistacea* 276, *281; scotophylla* 279, *281; spodochroa 281; subtortula 281; tortula 281; vanderbylii 281; violacea 281; xanthomelaena 281*
Parathalle 356; fueistingii 356
Parkerella 347, 348, 354, 356; populi 347, 348, 350, 357, 358
Parmelia 183, 185, 237, 240, 271, 272, 453, 611; subg Cyclocheila 271; subg Parmelia 271; sect Cyclocheila 271; sect Xanthoparmelia 184, 187, 188; ‘group’ Parmeliae 237; ‘group’ Xanthoparmeliae 242; adspersa 278; adusta 279; alabamensis 279; amazonica 278; americana 468; annexa 279; aptata 278; arcana 279; astricta 185, 240, 279; basutoensis 279; butleri 616; camtschadalis 468, 490; capnoides 280; caribaea 278; carneopruinata 278; caroliniana 278; cerussata 280; cinerascens 278; concrescens 278; condyloides 280; conformata 475; conranensis 280; corrugativa 278; costaricensis 471; crinita 475; cristifera 475, 476; crozalsiana 278; cryptochlorophaea 278; dilatata 475; dominicana 475; eborina 475; ecaperata 278; endosulphurea 475; epileuca 278; eruptens 278; *eximia 183*, 184, 190; *fausta* 183, *185*, 186, 190, 240; fumigata 280; hypotropa 476; ianthina 576; inhaminensis 278; inornata 278; *insignis* 183, 185, *186*, 187, 190, 240; *insipida* 237, *238*, 239, 243; interposita 280; intertexta 281; *inuncta* 183, *187*, 190; irregularis 188; ischnoides 280; laevigatula 462; latissima 475, 477, 490; lecanoracea 280, 577; *leptoplaca* 237, 238, *242;* leucosemotheta 476; lithophila 280; lithophiloides 188, 280; malaccensis 282; martinicana 278; microblasta 471; molybdiza 185, 280; mongaensis 280; murina 280; nairobiensis 278; nana 280; neoquintaria 280; *nimbicola* 237, *238*, 240, 243; norsticticata 278; numinbahensis 280; owariensis 280; peralbida 476; perlata 475, 490; praesorediosa 476; prolata 280; *pudens* 183, *188*, 190, 240; pustulescens 280; rahengensis 282; *ralla* 237, *240*-242, 244; raunkiaeri 278; reticulata 476; rodriguesiana 280; rupicola 281; salacinifera 279; schelpei 279; schenckiana 185; schistacea 281; scotophylla 281; scrobicularis 279; somaliensis 279; soyauxii 490; sphaerospora 184; spodochroa 281; *squamatica* 237, *242*, 244; subcrinita 476; subdecipiens 187, 188; subramigera 487; subtiliacea 279; subtortula 281; texana 279; tinctorum 476; tortula 281; unctula 187; vanderbylii 281; violacea 281; xanthina 476; xanthomelaena 190, 281; zambiensis 279; zimbabwensis 279
Parmeliella pannosa 474
Parmentaria astroidea 475
Parmotrema 272, 276; conformatum 475; crinitum 475; cristiferum 475, 490; dilatatum 475; dominicanum 475; eborinum 475; endosulphureum 475, 490; hypotropum 476; leucosemothetum 476; peralbidum 476; praesorediosum 476; reticulatum 476; subcrinitum 490; tinctorum 476, 490; ultralucens 476; xanthinum 477
Paxillus involutus 52
Peltigera didactyla 477; dolichorhiza 477; erumpens

[Peltigera erumpens]477; hazslinszkyi 477; spuria 477
Peltula 480; euploca 477
Peniophora nuda 334, 344; pseudoversicolor 344; violaceolivida 344
Perenniporia medulla-panis 341; tenuis 342
Peronosclerospora 407, 437
Peronospora tabacina 437
Pertusaria 74, 477, 490; albinea 459, 477; bispora 477; colobina 490; pustulata 478
Phaeographis dendritica 478
Phaeomarasmius 339; erinaceus 338, 339, 341, 345
Phaeophyscia hispidula 478
Phaeotrema 72; lacteum 79, 82
Phakopsora 540; apoda 546; gossypii 545; incompleta 546, 547; loudetiae 546; pachyrhizi 436, 548; setariae 547; vernoniae 516, 548
Phanerochaete arizonica 345; carnosa 345; chrysosporium 103; sanguinea 331, 332, 345; sordida 332, 333, 345; tuberculata 344; velutina 344
Phellinus ferruginosus 342
Phillipsiella atra 355
Phlebia albida 342; lilascens 343
Pholiota erinacea 339
Phragmocapnias 378, 381, 386, 388, 393, 394, 397, 399
Phyllopsora corallina 478
Physcia 479; adglutinata 490; aegialita 467, 491; alba 491; albicans 469; aspera 467, 491; biziana 478; callosa 478; insularis 459, 478; lacinulata 479; leucomela 470, 491; mexicana 478, 479; picta 467, 491; sorediosa 479
Physma byrsinum 479
Physopella africana 544; cameliae 546; hansfordii 544; hiratsukae 545; nyasalandica 517, 545; tecta 545; wiehei 517, 523, 545
Phytophthora 289, 314, 315, 407; cinnamomi 290, 292, 293, 296, 297, 299-304, 312-313; cryptogea 289-301, 303, 305-309, 312-315; drechsleri 289-295, 298, 299, 301-307, 309-315; erythroseptica 314; himalayensis 314; infestans 408, 437; megasperma 315; nicotianae 290, 292, 293; palmivora 290, 292, 295, 300, 302; richardiae 314; sinensis 303
Placodium isidiosum 463; murorum 463, 489
Placopsis cribellans 491
Platygloea 499, 500, 502; *acanthophysa* 499, *500-502*; *laplata* 325, *333*, 334, 340; mycophila 499; peniophorae 334; unicornis 501; unispora 499
Pleospora guadefroyi 166
Polyporus arcularius 339, 342
Poria terrestris 44
Porina 462
Porosphaerellopsis 355
Porosphaeria 355
Protoparmelia 237; badia 237
Protoparmeliopsis 237; muralis 237
Pseudocyphellaria 453; argyracea 479; aurata 454, 468, 479; crocata 480; mougeotiana v aurigera 480, 491; xantholoma 480
Pseudoparmelia 271-277; caperata 271-272; caroliniana 480; chapaadensis 271; cyphellata 271; dahlii 281; hypomilta 271; intertexta 272; leucoxantha 480; scotophylla 272; sphaerospora 271; texana 272
Psoroglaena cubensis 480
Ptychogaster 105
Puccinia 407, 521; absinthii 519; abutili 544, 548; aecidiiformis 517, 546; aframomi 544; africana 518, 547; ambigua 522; andropogonicola 546; andropogonis 545; anthriscicola 544; arenariae 544, 547; *artemisiae-afrae* 507, *518*, 519, 544; artemisiae-sibiricae 519; arthraxonis-ciliaris 544; aurata 518; bakoyana 520, 546; becii 520, 544; borreriae 520; brachypodii v arrhenatheri 545; v poae-nemoralis 547; calcitrapae 523; cardui-pycnocephali 436; carduorum 436; carthami 436; cenchri v africana 544, 546; cephalandrae 520, 521, 548; cephalandrae-indicae 521; chaerophylli 544; chaseana 544; cnici-oleracei 519; collettiana 532; conclusa 545; coronata 545; *crassocephali* 507, *521*, 545; cyathulicola 545; cynodontis 545; cyperi-cristati 545; cyperi-tagetiformis 545; desertorum 522, 545; dietelii 544; difformis 522, 545; digitariae-velutinae 545, 547; dimorpha 532; dummeri 523, 545; duthiae 544; echinopsis 523; emaculata 546; eritraeensis 544, 546; erlangeae 517, 523, 545; eucomi 546; exilis v hibisci 546; fimbristylidis 545; flaccida 546; fragilispora 508; fragosoana 546; fusispora 545, 547; garckiana 546; graminis 436; f sp tritici 408, 409; guizotiae 524, 545; hansfordiana 524, 547; hedbergii 524, 547; heterospora 547; holosericea 525, 546; hoslundiae 525, 546; hyparrheniae 546; hypoëstis 526; isoglossae 526, 546; kalchbrenneri 509, 545; v kalchbrenneri 526; v valida 526; keniensis 546; lantanae 526, 527, 544; lateritia 520, 528, 547; leonotidicola 528, 546; leptosperma 545; leucadis 529, 539, 546; leveillei 545; levis v panici-sanguinalis 544; v tricholaenae 547; lippiicola 529, 530, 546; lippiivora 529; lithospermi 522; loudetiae 546; macowanii 509; melanocephala 547; menthae 530, 547; morotorensis 545; nabugobo-ensis 547; nakanishikii 545, 547; natalensis 530, 546; v evansii 529; necopina 530, 531, 547; oahuensis 545; obscura 546; obscuripora 547; ocimi 531; perlargonii-elgonensis 547; palargonii-zonalis 546; pentadis-carneae 531, 547; petitiana 544; peucedani-kerstenii 547; phyllocladiae 544; pinarii 509; plectranthi 513; polygoni-amphibii 546, 547; polysora 548; pseudechinolaenae 547; pulvinata 523; recondita 409, 436, 544; rubiicola 531, 532, 547; rubiivora 532; ruelliae 532, 533, 547; saniculae 547; schizocarphae 521; semiloculata 533, 546; smilacis-kraussianae 547; sorghi 548; stobaeae v stobaeae 534; v woodii 533, 534, 544; tanaceti 519; *tetradeniae* 507, 534, *535*, 547; thunbergiae 533, 535, 544, 545, 547; thunbergiae-alatae 535; tragiae 547; vernoniicola 536, 548; versicolor 546; violae 548; zorniae 548

Pucciniosira dissotidis 536, 545
Punctelia 272, 274
Pycnoporus cinnabarinus 339, 341
Pyrenula aurantiaca 480; cerina 480; nitida 475
Pyrgillus javanicus 480
Pyricularia 147, 152; oryzae 437; buluoensis 152; fusispora 152; lauri 152; *sphaerulata* 147, *150-152*
Pyxine 491; berteriana 481; caesiopruinosa 481; cocoes 481; connectens 481; endoleuca 491; eschweileri 481; glebosa 462, 491; pringlei 481, 491

Ramalina 452; anceps 481, 482; ceruchoides 474; complanata 482, 492; dasypoga 491; denticulata 482; farinacea 491; furcellata 482, 491; indica 492; interponens 492; linearis 482, 492; peruviana 482; puiggari 492; soredientha 482; subasperata 492; subfraxinea 492; usnea 453, 481, 482, 488, 491, 492; usneoides 492
Ravenelia albiziae-zygiae 544; cassiaecola v berkeleyi 544; hansfordii 544; indigoferae 546; spegazziniana 105; tephrosiae 547
Relicina 274, 276, 611, 614, 615; abstrusa 612, 614; *agglutinata 611*, 613; *butleri* 611, *616;* circumnodata 612; *conglutinata* 611, *612*, 613; *dimethylbarbatica* 611, *612*-614; *fijiensis* 611, 613, *614*, 616; *filsonii* 611, 613, *615;* hirtifructa 614; limbata 615; *niuginiensis* 611, 613, *615*, 616; ramosissima 612; relicinula 615; samoensis 614; subabstrusa 615; sublanea 611
Relicinopsis 271-277, *281; dahlii 281; intertexta* 272, *281; malaccensis 282; rahengensis 282*
Resupinatus applicatus 340
Rhizomucor 84
Rhizopogon 193, 196, 197, 199, 200, 203, 204, 206-208, 213-218; stirps Luteolus 202; abietis 193, 194, 204, 205, 208, 209, 217; atlanticus 193, 194, 214, 215, 217; brownii 205, 206; cokeri 212, 214; couchii 193, 195, 196, 204, 205, 207, 209-212, 217, 218; evadens 193, 196, 210-212; v evadens 195, 211, 213, 217; fabri 193, 194, 199, 201, 216; fuscorubens 193, 195-197, 216; hesleri 218; lowii 198, 200; luteolus 52, 201; maculatus 215; nigrescens 193, 195, 197, 198, 216; parasiticus 215; piceus 201; roseolus 215; v intermedius 208; rubescens 193, 195, 202-205, 215, 216; separabilis 196; smithii 211; subaustralis 193, 195, 203-206, 208, 216; succosus 193, 194, 198-201, 208, 216; v *mexicanus 201;* superiorensis 198, 200; v mexicanus 200, 201; truncatus 193, 194, 212-215, 217; vinicolor 44, 47-49; vulgaris 193, 195, 204-212, 217, 218; v intermedius 208
Rhizopus 84
Rhodophyllus aeruginosis 129, 132; cyaneus 140; holocyaneus 129-132; mexicanus 142, 143
Rhynchostoma 93, 96-98; lageniforme 93, 94, 97, 98; minutum 93, 95, 96; rubrocinctum 95, 96
Rhytidiella 347; baranyayi 347, 357; moriformis 347, 358
Rinodina 493; contiguella 493; mamillana 493; thomae 493
Roccella 492; babingtonii 452, 482, 492; difficilis 492; galapagoensis 459, 483, 492; intricata 482; peruensis 482; portentosa 482
Roccellina badia 483
Roccellodea nigerrima 492
Russula 1, 32, 34, 46-48, 503-505; sect Ingratae 34; sect Rigidae 40; adusta 50; atropurpurea 504; caerulea 503; chloroides 504; cyanoxantha 504; fellea 504, 505; fragilis 50; grisea 40, 42; heterophylla 504; ochroleuca 1, 2, 25, 26, 29, 30, 32, 34, 40, 46, 48, 50, 504, 505; sardonia 50; vesca 40, 42; virescens 504; xerampelina 1, 2, 30, 32, 34-36, 38, 40, 42, 44-46, 48, 50 504

Sarrameana 353
Schistophoron tenue 483
Scorias 378, 381, 386, 388, 393, 394, 397, 399; spongiosa 380, 382
Scutellospora 169, 171, *179*, 219, 226, 228, 233, 234; *alborosea 180*, 226; *aurigloba 180*, 234; *calospora 180*, 219, 222, 228, 231, 233, 234; *coralloidea 181; dipapillosa 181; erythropa 181; fulgida* 219, *221*, 222; *gilmorei 181*, 222; *gregaria 181; heterogama 180; minuta 180; nigra 181; pellucida 181*, 219, 222, 226, 228, 229, 231; *persica 181; reticulata 181; savannicola 180*, 224; *tricalypta 180; verrucosa 181; weresubiae* 219, *224*-226, 228
Septobasidium 499, 501, 502
Seuratia 355
Sistotrema brinkmannii 343
Sphacelotheca reiliana 437
Sphaeria 250
Sphinctrina podocarpa 483
Spilonema revertens 483
Sporopodium leprieurii 484
Sporotrichum 105; azureum 105; pruinosum 103, 105; pulverulentum 103
Steccherinum fimbriatum 342
Stegobolus berkeleyanus 75
Stemphylium 107, 110
Stereocaulon 453, 494; apocalyptum 451, 494; *azulense* 451, 459, 467, 484, *494;* microcarpum 484; weberi 459, 484; wrightii 451, 494
Stereum 321; dichroum 321, 323; hirsutum 344
Sticta 453; aurata 454; filix 484; fuliginosa 484; quercizans 492; sylvatica 484; weigelii 484, 492; f peruviana 485
Strigopodia 378, 381, 382, 386, 388, 390, 393, 394, 396, 398, 399
Strigula 462; nitidula 485; subtilissima 485
Stropharia 138
Subulicystidium longisporum 335, 344
Suillus 45, 48, 50; luteus 47
Sulcaria 113-115; badia 114; *isidiifera* 113, *115*, 117; sulcata 114; virens 114

Tapellaria 462; epiphylla 462, 485; nana 469, 485; nigrata 485

Teloschistes chrysophthalmus 142; exilis 492; flavicans 485, 493
Tephromela atra 485
Thaxteria 354
Thelotrema 72; allosporoides 75; depressum 80; elachistoteron 72; glaucopallens 79, 82; *guptei* 71, *79*, 82; lacteum 79; massalongoi 80, 82; polillense 80, 82; pycnophragmium 76; reclusum 74; recurvum 71, 80, 82; terebrans 76
Thermomucor 84; indicae-seudaticae 86
Thermophymatospora 99, *100; fibuligera* 99, *100*, 102-104
Tilletia caries 437; controversa 437; foetida 437; indica 408, 437
Tomentella ferruginea 343; molybdaea 335, 336, 343; pilosa 342; ramosissimum 343; subtestacea 336, 337, 342
Trapelia coarctata 485
Trapeliopsis granulosa 485
Trechispora farinacea 336, 337, 343; vaga 343
Trematosphaeria lignatilis 161, 166
Tremellostereum 321, 323; *dichroum* 321-*323*
Tricharia vulgaris 486
Trichobasis palmarum 259
Tricholomopsis platyphylla 337, 338, 341
Trichomerium 378, 381, 386, 388, 390, 391, 397, 399
Trichopeltheca 378, 381, 382, 386, 388, 390, 391, 396, 398, 399
Trichosphaeria 93
Triposporiopsis spinigera 378
Troposporella fumosa 358
Trypethelium eluteriae 486; mastoideum 486; ochroleucum 486; tropicum 486
Tubeufia 356
Tubulicrinis 361, 369, 374; borealis 361, 363, 365, 369, 370; calothrix 344, 361, 363, 365, 369; glebulosus 364; gracillimus 361, 364, 365, 369; medius 361, 365, 368, 369; strangulatus 361, 363, 365, 370; subulatus 361, 365, 371

Ulocladium 107, 110
Uredo 512, 533, 540, 545; achyranthicola 544; bidenticola 540; caricis-confertae 544; clerodendricola 536; clerodendrina 536, 537, 544; desmodii-ramosissimi 545; dissotidis 536; ecteinanthi 538; fuirenae-strictae 545; humbertii 537, 545; *hypoëstis-verticillaris* 507, *537*, 546; *isoglossae* 507, *538*, 546; kabaleensis 547; kabanyoloensis 544, 550; *leucadicola* 507, *538*, 546; mitteri 538; montis-elgonensis 544; paederiae 507, 539, 546; palmarum 259; palpigera 539, 540, 546; pycnostachydis 513; ruelliae 532; scholzii 515; sporoboli-pyramidalidis 547; stylosanthis 547; xyridis 548
Uromyces 542; appendiculatus 547; aspiliicola 540; bidenticola 540, 544; blainvilleae 540, 544; clignyi 544, 546, 547; cluytiae 545; commelinae 544-546; crotalariae 545; dipcadi 545; eulophiae 545; euphorbiae 545; geranii 545; hobsonii 541, 546; hyparrheniae 546; hypoëstis 537; indigoferae 546; ipomoeae 541, 546; keniensis 544; linearis 546; melantherae 542, 546; notabilis 545; pegleriae 545; pseudarthriae 547; rhynchosiae 547; *sasaënsis* 507, *542*, 547; setariae-italicae 544-547; striatus 546; tenuicutis 547; transversalis 545; valerianae 542; valerianae-wallichii 542, 543; vignae 548; wiehei 547
Usnea 493; amabilis 493; antillarum 486; arthroclada 487; barbata 493; ceratina 493; cladocarpa 487; longissima 493; paradoxa 487; plicata 453, 493; rubescens 487; rubiginea 487, 493
Ustilago scitaminea 437

Xanthoparmelia 276, 277, 563, 565, 569, 571, 574-576, 579-581, 583, 584, 587-589, 591-593, 595, 596, 599-601, 604, 605, 607, 610; *acrita* 563, *564*, 565; adhaerens 582; *africana* 563, *564*, 565; albomaculata 602, 608; *aliphatica* 563, 565, *566*, 567, 600; australasica 568; austroafricana 598; barbellata 592; *barklyensis* 563, 565, *566; calvinia* 563, *567*-570; *capensis* 563, *567*, 569; cedrus-montana 604; *ceresensis* 563, *568*, 569; chlorochroa 576; colorata 570; *competita* 563, 567, *568*-570; conspersa 568; constrictans 597; *crassilobata* 563, *570*, 571; cumberlandia 580; *denudata* 563, *570*, 571, 598; *diacida* 563, 571, *572;* dichromatica 602; *duplicata* 563, 571, *572*, 591; *effigurata* 563, *573*, 575 586; encrustans 606; *endochromatica* 563, *574*-576, 580, 598; endomiltoides 576, 588; *enteroxantha* 563, *574*, 575; *epigaea* 563, 573, 575, *576; equalis* 563, *576*, 579; *esterhuyseniae* 563, *577*, 579; *evernica* 563, 567, *577*, 579, 596; exornata 586; *globisidiosa* 563, *578*, 579; *gyrophorica* 563, 574, *578*, 581; huachucensis 572; *hybrida* 563, *580*, 581; hypoleia 573, 585, 604; hypoprotocetrarica 603; hyporhytida 572; *ianthina* 563, *576; indumenica* 563, *580*, 581; kalbii 596; *karooensis* 563, 581, *582*, 592; *lagunebergensis* 563, 577, *582*, 583, 596; *lecanoracea* 563, *577; lesothoensis* 563, *582*, 583; leucostigma 574, 580; *lividica* 563, 583, *584*, 592; *lobulifera* 563, 583, *584;* luminosa 594, 603; *minuta* 563, *585*, 587, 591; *mollis* 563, *585*, 587; molliscula 577; mougeotii 594; mougeotina 585; *namakwa* 563, 573, *586*, 587; *namaquensis* 563, *586*, 587; neocongensis 592; *neosynestica* 563, *588*, 589; *neotasmanica* 563, *588*, 589; nigropsoromifera 572; *nuwarensis* 563, 589, *590*, 609; *ochropulchra* 563, 589, *590; olifantensis* 563, *591*, 593; *olivetorica* 563, 574, 584, *591*, 593; *oribensis* 563, *592*, 593; phaeophana 590; *probarbellata* 563, *592*-594; *pustulifera* 563, *594*, 595; *rubro-medulla* 563, *594*, 595; *saniensis* 563, 595, *596;* schenckiana 572; *serusiauxii* 563, 577, 578, 582, 595, *596; simulans* 563, *597*, 599; *skyrinifera* 563, *597*, 599; *stenosporonica* 563, 574, *598*, 599; *subcolorata* 563, 572, 597, *598*, 599; *subcrustosa* 563, *600*, 601; subdecipiens 567, 600, 606; subdomokosii 582, 592;

[Xanthoparmelia] suberadicata 577, 597, 602; *subnigra* 563, 566, *600*, 601, 606; *subochracea* 563, 601, *602;* subramigera 487; *subruginosa* 563, 585-586, 601, *602; surrogata* 563, 594, *603*, 605; synestia 588, 590, 594, 609; *tablensis* 563, *603*, 605; taractica 570, 604; tasmanica 566, 590, 603; *terricola* 563, *603*, 605, 609; *thamnolica* 563, *604*, 605; *toninioides* 563, *606*, 607; *transvaalensis* 563, 566, 602, *606*, 607; *treurensis* 563, 578, 607, *608; tumidosa* 563, 602, 607, *608; viridis* 563, 590, *609*, 610; *wesselsii* 563, *609*, 610
Xanthoria candelaria 487
Xenasmatella 361, 373; allantospora 361, 365, 372-374; tulasnelloidea 361, 365, 373, 374

Zignoella lichenoides 486; magnoliae 486; nobilis 486
Zoophthora 268; forficulae 263, 268

REVIEWERS, VOLUME TWENTY-SEVEN

The Co-Editors express their appreciation to the following individuals who have, prior to acceptance for publication, reviewed one or more of the papers appearing in this volume.

M. E. Barr Bigelow
T. Baroni
J. Boise
P. A. Bowler
M. Christensen
G. B. Cummins
R. Currah
E. E. Davis
G. S. De Hoog
H. Dörfelt
C. Dorworth
W. M. Dowler
R. S. Egan
J. A. Elix
W. Gams
R. L. Gilbertson
M. E. Hale, Jr.
R. T. Hanlin
D. M. Henderson
L. Holm
J. Hopkins
D. Hosford
R. Hunt
P. W. James
E. B. G. Jones
B. Kendrick
R. G. Kenneth
P. Kirk
R. E. Koske
P. Lanquetin
F. F. Lombard
B. Lowy
N. Lundqvist
D. Malloch
G. Morgan-Jones
A. Onions
S. Onofri
A. Rambelli
D. J. Read
R. Roberts
J. D. Rogers
D. J. Royse
R. Santesson
N. C. Schenck
K. Seifert
V. Shindler
R. E. Stevenson
E. L. Stewart
P. W. Tooley
J. M. Trappe
K. Wells

MYCOTAXON PUBLICATION DATE

Volume **26** (July-September 1986) July 15, 1986

ERRATUM, VOLUME TWENTY-TWO

Page 507 line 23 *for* republished
read redrawn to show the hooked paraphyses

ERRATA, VOLUME TWENTY-SIX

Page 83 line 17 *for* 7-7-95-A *read* 7-7-85-A

Pages 297-298: These pages were withdrawn by the Managing Editor when he discovered that the article accepted for those pages by Cryphal, A. P. O., entitled "On monotypic and specious genera," had previously been published in Phytopathology **46:** 411-412. 1956 (cited in Mycotaxon **6:** 194. 1977).

ERRATA, VOLUME TWENTY-SEVEN

Page	46	line	33	for	Russla	read	Russula
	75		25	for	*Stegobolous*	read	*Stegobolus*
	119		22	for	Papulasporea parasiticum		
				read	Papulospora parasitica		
	137		3	for	*farinacea*	read	*farinaceum*
	263		29	for	*E.*	read	*Entomophthora*
			35	for	*E.*	read	*Empusa*
			42	for	*E.*	read	*Entomophthora*
	264		14	for	*E.*	read	*Empusa*
	266		12	for	*E.*	read	*Empusa*
			24	for	*Entomophthora*	read	*Empusa*
	268		17	for	*E.*	read	*Erynia*
			25	for	*E.*	read	*Empusa*
	273		3	for	Pseuodparmelia	read	Pseudoparmelia
	287		19	for	C.	read	Claussenomyces
	343		9	for	**ramossissimum**	read	**ramosissimum**
	344		6	for	**anasaziensis**	read	**anasaziense**
	355		35	for	**Philippsiella**	read	**Phillipsiella**
	384		48	for	fernandezana	read	fernandeziana
			49	for	walterii	read	walteri
	409		28	for	cinerens	read	cinereus
	436		3	for	paracitica	read	parasitica
	459		10	for	*galapagense*	read	*galapagoense*
	489		25	for	*guadeloupense*	read	*guadelupense*
	490		25	for	*granulata*	read	*granulatum*
	507		10	for	A. echuyaënsis		
				read	Aecidium echuyaënse		
	510		1	for	echuyaënsis	read	echuyaënse
			2	for	echuyaënsis	read	echuyaënse
	545		50	*for*	quizotiae	*read*	guizotiae
			52	*for*	echuyaënsis	*read*	echuyaënse

[CONTENTS continued from inside front cover]

Author INDEX 617
INDEX to Fungous and Lichen Taxa 619
Reviewers 627
Publication date, MYCOTAXON Volume 26 627
Errata 628

[MYCOTAXON for July-September 1986 (**26:** 1-520) was issued July 15, 1986]

CO-EDITORS OF MYCOTAXON

G. L. HENNEBERT
FRENCH LANGUAGE EDITOR
& BOOK REVIEW EDITOR

UCL, Place Croix du Sud 3
B-1348 Louvain-la-Neuve, Belgium

RICHARD P. KORF
ENGLISH LANGUAGE EDITOR
& MANAGING EDITOR

P.O. Box 264
Ithaca, NY 14851, USA

MYCOTAXON is a quarterly journal devoted to all phases of mycological and lichenological taxonomy and nomenclature. It seeks to publish all papers within 5 months of submission, using photo-offset lithography. All articles are reviewed by specialists prior to acceptance. Publication is open to all persons. Papers may be in French or English, with one or more summaries in any language.

SUBSCRIPTION INFORMATION

Each issue of MYCOTAXON varies in number of pages. Each volume, beginning with volume 3, contains at least 512 pages, and consists of an irregular number of quarterly issues. Subscriptions are on a *per volume* basis, *not* on an annual basis. If only one billing during each year is a requirement, please pay for 2 or 3 volumes which will normally cover one year's issues; when more volumes are published in one year than have been paid for, the following year's invoice will include the unpaid volume. Personal subscriptions are available at a substantially reduced rate for *individuals* who agree not to deposit their copies in another library than their personal one within 3 years of receipt. All back volumes are still available. Prices for each volume are:

REGULAR (multiuser)	$48.00 US
PERSONAL (individual)	$21.00 US

(*Complete runs*, volumes 1 through the latest complete volume, are subject to a **20% discount** for new subscribers; old subscribers who wish to *complete* their set may purchase missing volumes at the 20% discount.)

MYCOTAXON may also be obtained on a journal-exchange basis. This may be arranged with journals, institutions, or individuals who have difficulty in obtaining foreign currencies. For details, write a Co-Editor.

TWENTY-VOLUME CUMULATIVE INDEX, 1974-1984

MYCOTAXON CUMULATIVE INDEX FOR VOLUMES I-XX (1974-1984) by Richard P. Korf & Susan C. Gruff (ISBN 0-930845-00-5) is available at $17.50 *postpaid* from MYCOTAXON, LTD., P.O. Box 264, Ithaca, NY 14851-0264 USA.

AVAILABILITY IN MICROFORM, & TEAR SHEET SERVICES FOR ARTICLES

MYCOTAXON is also available in *microfiche* and in *microfilm* from University Microfilms, 300 North Zeeb Road, Ann Arbor, MI 48106 USA or 30-32 Mortimer Street, London W1N 7RA, England, from whom prices may be obtained.

Tear sheets of individual articles appearing in MYCOTAXON may be obtained through OATS, Institute for Scientific Information, 3501 Market Street, Philadelphia, PA 19104 USA, from whom prices may be obtained.

EDITORIAL SERVICES & INFORMATION FOR PROSPECTIVE AUTHORS

Authors prepare their own *camera-ready* copy after having received comments from pre-submission reviewers. Detailed *Revised Instructions to Authors* appeared in MYCOTAXON **26**: 497-510 (1986). A copy of these instructions will be sent upon request to one of the Co-Editors.

We are able to provide prospective authors with two aids to publication. Both are sold at our cost, and may be ordered from MYCOTAXON, LTD., P.O. Box 264, Ithaca, NY 14851-0264 USA.

SPECIAL MANUSCRIPT PAPER is available in pads of 50 sheets, and is ruled in blue, non-photoreproducing ink for both sizes of typeface (pica and elite) called for in the instructions to authors, and for non-reduction copy. It is a convenience to typists, but certainly not essential, since rectangles of the appropriate size can be prepared on any paper using a non-photoreproducing blue pencil. Each pad of 50 sheets is shipped by *postpaid* surface mail for $2.50.

BIOPLATE is a special sheet of transfer letters designed by the Managing Editor for use in the preparation of plates and graphs for publication. It is manufactured for us by Prestype, is approximately 30 × 39 cm, with a wide assortment of numbers, letters (including important Greek characters), symbols, arrows, etc. Currently available only in black, sheets are shipped by *postpaid* surface mail for $4.95.